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PAPERS

CONNECTED WITH

THE PERIAR IRRIGATION PROJECT IN MADRAS.

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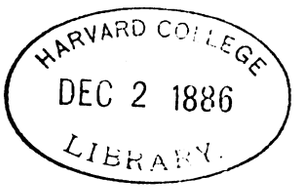

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PAPERS

CONNECTED WITH

THE PERIAR IRRIGATRION PROJECT IN MADRAS.

Report by Major J. Pennycuick, R.E., on the Project for the diversion of the Periar River for the purposes of irrigation in the Vigay Valley.

The proposals herewith submitted are for the diversion of the waters of the Periar into the valley of the Vigay, and for their distribution for purposes of irrigation in the latter valley.

Objects of proposals.

2. They include—

1st.—The construction of a dam to close the valley of the Periar, and to store 13,300 millions of cubic feet of water, of which 6,815 millions are available for irrigation.

2nd.—The construction of a tunnel through the watershed ridge between the two valleys, for the purpose of drawing off the water from the reservoir thus formed, with the necessary sluices and subsidiary work for controlling the supply.

3rd.—The necessary works for controlling the supply from the Periar down the valley of the tributary* by which it reaches the Vigay, and for keeping this supply separate from the natural supply of the tributary in question.

* Called the Soorocolly.

4th.—The works necessary for the regulation and distribution of this supply for the irrigation of 140,000 acres of land in the Vigay valley.

3. The first and second sets of works will be considered under the general designation of "Head Works," the third under that of "Regulating Works," and the remainder under that of "Distribution Works."

4. The present condition of the country to be supplied cannot be better described than in the language used by the late Major Ryves, R.E., in his report upon this project dated 7th August 1867—

Condition of the country to be supplied.

"The principal division of the Madura District, consisting of the three talooks, Meyloor, Madura and Tirumungalum, is a strip of country running north and south; its eastern boundary marching with the adjoining zemindary estates of Shevagunga and Ramnad, and on the west separated from the Dindigul division of the district by the mountains and jungle which extend almost continuously from Nattom on the north to Srivilliputur on the south, where they run into the general range of the Western Ghauts, which here separate British territory from the Travancore country.

"Its area, excluding uninhabited mountain and jungle, is about 1,200 square miles, with a population of very nearly half a million.

"The Vigay river, passing through the only opening in the hills which form the western boundary, flows across the strip; the length of its course within the limits above defined being about 33 miles. In this length several river channels are taken off, most of them to fill tanks during the short and uncertain periods of Vigay freshes. The principal channels are the Vadakurry, the Tenkurry, the Nellayoor, and the Madacolum.

"Vaid"—north.
"Kurry"—ban.
"Ten"—south.

"The two first named have the advantage of anicuts across the river at their heads; the other two as well as all the other channels are supplied by means of temporary spurs (made of grass and sand—corumboos) run out into the river.

"The numerous tanks supplied by the channels were many of them first class reservoirs originally, but are now so silted up as to be capable of storing not much more than half the quantity of water they were designed to hold; they occupy a great deal of valuable land, and, in the attempt to get as much water as they require, the ryots of one tank frequently cause injury to their neighbours above them, damming up their escape calingulahs and flooding land by the extended water-spread.

"The tanks having become shallow in proportion to the area of the water-spread, there is enormous waste of valuable water by evaporation. I calculate that this waste amounts to at least thirty per cent. of the water stored.

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"The character of the Vigay makes the tanks system essential. For some reason or other the quantity of water received into the channel of the river bears a very small proportion to the rainfall on its catchment basin, the average annual rainfall registered at Periacolum and Madura is 32 and 41 inches respectively. On the Cumbum valley (where no register has been kept), it is at least as much as at Periacolum; in the Wursanaad valley it is probably less. Taking it at only 33 inches over the whole catchment basin above the Peranny, it would amount to 3,600 millions of cubic yards per annum, and supposing that only one-third of this found its way into the streams and rivers so as to be available for irrigation, there would be more than enough (with due allowance for the enormous waste on tanks) for three times the extent of paddy crop now raised.

"Yet it is affirmed by good authority that, in an average year, not a drop of Vigay water reaches the sea; but this I think is hardly sufficiently well established to be accepted as the fact. My belief is that sufficient water for more than double the present area of irrigation does flow down the Vigay, but that three-fourths of the annual supply passes down the river at three times the rate at which all the channels together can draw off water from it, so that if the big freshes could be detained, so as to spread over, say 60 days, instead of running off at three times the rate in 20 days, it would be found that there would be water enough (if the tanks could contain what it would be necessary to store) for double the area of rice-crops.

"However this may be, there is no doubt as to the main fact that the supply of water obtained from the Vigay is so precarious and scanty that even in good years the paddy crop barely covers 22,000 acres annually, although the existing channels and tanks command land enough, and have sufficient hydraulic capacity, for the irrigation of fully double that extent of crop if only a sufficient supply of water, delivered at a regular moderate rate, be ensured.

"This Vigay irrigation is situated in the Madura talook, the middle one of the three named above. In the Meyloor talook, there is but one river, and that but a small stream, at its northern extremity, under which a small extent of land receives a good and certain supply. All the rest of this talook is dependent for irrigation on the local surface drainage, stored in small shallow tanks, the majority of them being mere ponds. Situated as all the land of this talook is within a few miles of the water-shed, there are no well defined streams; the Alligiry hills form a dyke turning all the hill streams to the north and south round the flanks of the talook.

"The north-east monsoon, from which this talook receives what rain it does get, is very uncertain so far south and inland, and the mountains to the west of it (the streams from which, as above shown, do not flow through this talook) no doubt draw away from it a considerable proportion of the rain cloud which may have travelled so far.

"Under these circumstances, it is not surprising that agricultural operations are but seldom rewarded by a good crop. If the ryot is so fortunate as not to find the ground as hard as brick at the ploughing season, the chances are that rain necessary to bring the crop to maturity will not fall at the expected time.

"And the cultivation of wet crops is hardly a less precarious business, failure being attended with greater loss, and success attained generally at much expense of labour and money on raising water from wells and pools.

"Almost every alternate season is one of scarcity in this talook, and, when an exceptionally dry year occurs, there is severe distress, and the population is thinned by death and emigration. In 1861-62, and again last year, it suffered severely in this way.

"If the water-supply in the Vigay were sufficient, half of Meyloor could be irrigated from it."

5. To this it may be added that during the famine of 1876-77 ₹4,32,170 were expended on relief works and ₹7,92,047 on gratuitous relief in the Madura district, while in the neighbouring districts of Trichinopoly and Tinnevelly, which are partially protected by irrigation, the expenditure on relief works was ₹3,85,394 and ₹1,48,110 respectively, and on gratuitous relief ₹1,20,626 and ₹1,27,901.

6. While such is the condition of the Madura district, on the other side of the water-shed line, which divides it from the Travancore territory, is an enormous area of uncultivated and uninhabited jungle, with a yearly rainfall of upwards of 100 inches, and with water running to waste in every direction.

Previous attempts to increase the supply of the Vigay.

7. The idea of utilizing the water falling on the Travancore side of the watershed for the augmentation of the supply of the Vigay is no new one, and one or two of the minor tributaries of the Periar have actually been diverted for this purpose.

8. As long ago as 1808, the late Sir James (then Captain) Caldwell reported on a proposal for diverting the waters of the Periar itself into the Vigay valley. He condemned the project as "decidedly chimerical and unworthy of any further regard" than was involved in the taking of levels to a distance of 400 yards from the Periar up one of its tributaries.

History of the present project.

9. The subject appears to have been discussed again from time to time, but it was not until 1867 that it was brought forward by Major Ryves in a really practical form.

Major Ryves' proposals of 1867. (See Sheet No. 1.)

10. Major Ryves' proposals as detailed in his report of the 7th August 1867 included an earthen dam 162 feet in height, at the site marked No. 1 on the general surveys; the escape crest was to be at 142 feet above the river bed, and the water was to be diverted into the Vigay valley by a cutting through the watershed at the point marked A, having its sill 17 feet below the escape crest, and a maximum depth of about 52 feet.

11. No provision was made for controlling the discharge through the watershed cutting; but in order to prevent a discharge into the Sooroolly beyond what that stream could safely

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carry, it was proposed to construct a reservoir with a capacity of 945 millions of cubic feet at some point between the latter and the watershed.

12. No other provision for storage was made, the project being essentially one for the diversion of the river and not for storage of water.

13. The proposals were accompanied by an approximate estimate based upon such information as was at Major Ryves' disposal at the time, and, on the strength of this, orders were issued for the commencement of the detailed investigation necessary for the preparation of accurate estimates of cost and returns.

Further investigations.

14. These investigations, which were at first under the charge of Major (then Lieutenant) Pennycuick, R. E., and after that officer's departure on medical certificate to England in 1870, under that of the late Mr. R. Smith, were actively prosecuted during 1868 and the three following years.

15. It does not appear necessary to give in detail the history of these investigations, the result of which was to introduce considerable modifications into Major Ryves' original scheme while maintaining its essential features.

(Sheet No. 1.)

16. Two sites, marked No. 2 and 3 on the general surveys, were examined and found to possess material advantages over No. 1; but these were ultimately abandoned in favour of the site marked No. 4, seven miles lower down the river, which was found to be in every respect superior to the upper sites.

17. The river bed here is 34′ lower than at No. 1 site, but by its adoption the water can cross the watershed at the point marked B, which is 47′ lower than A, showing a saving of 13′ in the height to be overcome. The ground between the two sites (1 and 4) is flat and open as compared with that above No. 1, so that a dam 168′ high at No. 4 stores more than double the quantity impounded by a dam of 220′ at No. 2, while the drainage area available at No. 4 is 305 square miles against 250 at No. 2.

18. No. 4 site was therefore definitely adopted, and it was further decided that the relative levels of dam and offtake should be such as to allow of the storage of sufficient water to overcome all fluctuations in the discharge of the river, and to allow a regular and equable supply to be passed, under complete control, from the reservoir into the Sooroolly valley.

Mr. Smith's proposals of 1872.

19. A project complete in all details was finally submitted by Mr. Smith in April 1872.

20. Mr. Smith's proposals included—

1st.—A dam 171′ in height, to be constructed of earth by the "Silting" process, of which much was at that time expected, with an escape 400′ in length blasted out of the saddle on the right flank of the dam. The construction of the dam involved, as a subsidiary work, the excavation of a tunnel 423′ in length with an area of 1,064 square feet, with cuttings at each end aggregating in contents nearly 4½ millions of cubic feet, for the passage of the water during the construction of the dam.

2nd.—A tunnel 7,000′ in length under watershed ridge, with cuttings leading up to its two ends. The sill of the cutting on the lake side was to be 113′ above the river bed, the space between this level and that of the escape crest 144′ amounting to 6,815 millions of cubic feet being available for storage of water.

For controlling the entrance of the water into the tunnel, an elaborate system of regulating sluices estimated to cost no less than ₹71,000 was provided.

3rd.—A series of regulating sluices for passing the Periar water round the flanks of the anicuts on the Sooroolly.

4th.—Works for the distribution of water for the irrigation of 150,000 acres of land in the Madura and Meyloor talooks.

The works under the third and fourth heads are identical with those now proposed.

21. The total cost of the project was estimated at ₹53,99,700 exclusive of interest, indirect charges, and any payment to the Travancore Government for the use of the water.

The returns were estimated at ₹6,94,000 less ten per cent. for maintenance.

22. Mr. Smith's proposals were approved by Colonel Oakes, who was officiating as Chief Engineer for Irrigation at the time of their submission, as well as by Colonel Mullins, who resumed charge of the Office shortly afterwards; but the execution of the project was opposed by Major-General Walker (the Chief Engineer, Public Works Department), mainly on the ground that sufficient experience had not been gained of the "Silting process" to justify our trusting to it for a work of such magnitude.

He suggested consideration of certain alternative arrangements, by which it was thought that the objects in view might be at least partially attained, without the expense and risk of failure attending the execution of the complete project.

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23. The Government of Madras adopted General Walker's views so far as to decline to recommend the project for execution, and, after some further discussion, Mr. Smith and Captain Pennycuick were directed to submit a joint report as to the feasibility of adopting General Walker's proposed modifications.

Subsequent discussion.

24. Their report was altogether adverse to these proposals, which had in fact been already considered and abandoned, and it was shown that the project must be carried out in its completed form or not at all.

25. This report was accompanied by a separate note by Captain Pennycuick, which contained the first proposal for the substitution of a masonry dam for one of earth; in this note it was pointed out that the subsidiary works in connection with the earthen dam, notably the temporary escape, the necessity for which was not recognised when the project was first brought forward, had so raised its probable cost as to render it doubtful whether the masonry dam would not be actually the cheaper of the two, while it would be free from the elements of uncertainty attending the use of earth in any form.

26. In the meantime an investigation of the probable returns was undertaken by an Officer of the Revenue Settlement Department, and his report, which is the basis of the Revenue estimates as now submitted, was to the effect that an ultimate net return* of ₹ 5,99,000 might fairly be looked for.

* After deduction of maintenance charges.

27. No further action of a practical nature was taken during the six years which followed the submission of the note above mentioned; but there was a great deal of discussion of a more or less desultory nature, in the course of which the arrangements for the construction of a dam were matured and brought into shape, while the conviction of the substitution of masonry or concrete for earth was a necessity, was gradually deepened in the minds of all the officers who took part in the discussion.

28. Finally the whole of the papers connected with the subject were handed over to Major Pennycuick, who was directed by an order, dated the 8th May 1882, to be relieved of other duty with a view to his undertaking the revision of the plans and estimates for the whole project.

The present report is submitted in accordance with these orders.

29. A considerable amount of the work to be done being of a novel or unusual character, it will be necessary in many cases to explain in some detail the reasons for the proposals made, and the arguments for and against the conclusions arrived at. Before entering on this portion of the subject, it seems desirable to state, concisely and without interruption or digression, the actual course proposed for adoption.

Present proposals.

30. The dam is to be constructed at the site shown on the plans, and to have the section shown in detail on sheet No. 4; the height is to be 155′ from the bed of the river to the top of the dam proper, above which is a parapet 5′ in height and 4′ in thickness. The thickness of the dam proper is 12′ at the top and 115¾′ at the lowest part; it is to be constructed throughout of concrete composed of 25 parts by measure of hydraulic lime (ground but not slaked) 80 of sand, and 100 of broken stone.

Main dam.

The front face is to be plastered with plaster composed of equal parts of lime and sand.

31. The lime will be ground, the stone broken, and the concrete mixed by machinery driven by a turbine, the power for working which is obtained from the river itself.

32. The concrete will be conveyed from the machines to the point where it is required for use by a wire tramway, and rammed by the machine shown in detail on sheet No. 9.

33. A temporary dam 30′ in maximum height will be constructed above the site of the main dam, and a similar dam 10′ in height below that site, to enable the site to be completely cleared and the foundation trenches blasted out before the main dam is begun. These dams will be constructed of material similar to that of the main dam.

Temporary dams.

34. In order to provide for the passage of the river water during construction, two culverts, with an area of 96 square feet each, will be cut through the rock on the left bank of the river; they will be closed by an equilibrium shutter, with gearing so designed that the velocity through the culvert can never exceed 20′ per second, but that subject to this limit the gate shall open or close 3′ for every foot of rise or fall in the level of the water above the dam.

Escape culverts.

35. On the right bank will be a similar culvert with one-fourth of the area for supplying the turbine which drives the manufacturing machinery; the gearing for the shutters of this

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culvert will be so arranged that, under ordinary circumstances, it will pass only the amount of water required for the turbine; but that, on an emergency, it may be made to pass any quantity up to a maximum of 960 cubic feet per second, giving a maximum velocity of 20′ per second.

36. The two culverts will thus pass, if necessary, 4,800 cubic feet per second, and, so long as the discharge of the river does not exceed this amount (that is for 19 days out of 20), the water level above the dam may be maintained at any desired level, from which it will not vary by more than 2′ at the most.

The effect of discharge greater than the above amount will be considered hereafter.

37. For the formation of escapes two saddles, one on each bank, will be utilized. The one on the right bank has solid rock at a minimum level of 154′ above the river bed, and will be cut down for a length of 420′, to a level of 144′.

Permanent escape.

38. On the left bank the solid rock is at a level of 104′, and the saddle will be built across with material similar to that of the main dam to the same level (144′) as that of the righ) bank escape. The wall thus formed will have a length on its crest of 403′, and a further length of 97′, making 500′ in all, will be obtained by cutting away the rock at its two ends.

39. The two escapes will thus have an aggregate length of 920′.

40. At a distance of 60′ from escape wall on the left bank will be built a second wall, 10′ in height, with its crest 30′ below that of the first wall, to form a water cushion.

41. In the Muliapaujan* valley at 113′ above the river bed will be started a cutting, running northwards, 21′ broad with a fall of one in 440′. When the depth of the cutting (in rock) reaches 30′, which will be at a distance of 5,400′ from its starting point, it will be replaced by a tunnel with an area of 80 square feet and a fall of one in 75. At its lower end the tunnel will communicate with the bed of the small stream (the Mulia Paujan), up whose valley the Goodalur ghat now runs, by a cutting similar to that at its southern end; his cutting is 160′ in length, the tunnel being 6,650′.

Watershed suttings and tunnel.

* A tributary of the Periar, see sheets Nos. 1 and 14.

Sheets Nos. 15 and 16.

42. At the entrance of the tunnel will be constructed an equilibrium sluice similar in principle to that used for the escape culverts under the main dam, by which the discharge can be either regulated at pleasure or maintained automatically at any fixed amount.

43. The existing Goodalur ghat on the main line of communication between Madras and Travancore passes close to the mouth of the tunnel, about eight miles from the site of the dam. From its point a road will be constructed to the site, for the conveyance of materials, stores, &c.

Communication with site.

44. Traction engines will be used for the purpose, as the nature of the ground admits of a remarkably favourable trace, there being no gradient against the traffic of more than 1 in 600, while fuel is cheap and animal power exceedingly dear.

Arrangement for transport.

45. For the conveyance of lime, grain, and all materials which can be carried in small parcels up the ghat, a wire tramway will be used, the ghat road being only used for articles too heavy to be carried in this manner.

46. The reasons which have led to the adoption of the transport arrangements proposed will be discussed hereafter.

47. Buildings for the accommodation of officers and subordinates and lines for labourers will be constructed on the sites shown, all building materials except lime (of which very little will be wanted) being procurable in abundance.

Buildings.

48. From the mouth of the watershed tunnel the Periar water will pass by the Vyravenaar into the Sooroolly river.

Regulating works on the Sooroolly.

49. The "regulating works" between the mouth of the watershed tunnel and Vigay are shown on the drawings numbered under that head from 1 to 11.

50. Of these the first six are survey and section of the valley of the Sooroolly, and a portion of the tributary (the Vyravenaar) by which the Periar water reaches it.

51. The remainder are detailed drawings of the regulating works themselves.

52. Of these latter there are 13 sluices, one according to Plan No. 7, two according to No. 8, seven according to No. 9, and three according to No. 10.

53. Mr. Smith's original scheme provided a 14th sluice (according to Plan No. 7) for the Cumbum anicut on the Vyravenaar; but this was considered unnecessary by Major Oakes, as there is here hardly any defined river bed, and the flood waters now spread over a large area of country so that there is no objection to the Periar water being allowed to do the same; the

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anicut is situated in a most unhealthy spot, and it would be well that no work connected with the project should be carried out there. The possible waste of Periar water by its being used for the supply of the Cumbum tank is insignificant.

54. These sluices are all similar in principle, the differences in detail being due to local conditions and to the amount of fall available at each site. Their object is to pass the Periar water round the different anicuts, without interference with the channels fed by the latter, none of which are provided with head sluices, and they have been planned to discharge the maximum volume of Periar water which will be allowed to flow into the Sooroolly, when the surface level of the stream above each anicut is flush with the bed of the existing channel and taken off from it.

55. It is an open question whether it would not be better to build head sluices to the Sooroolly channels and pass the Periar water over the anicuts; but if this were done, the project would have to bear a portion of the cost of annual repairs to these latter, many of which are of doubtful stability, while, in the event of them being breached or seriously injured, it might be necessary for the whole Periar supply to be shut off while repairs were being executed.

56. This latter consideration appears to have rightly determined Mr. Smith to adopt the arrangement here proposed, though somewhat more expensive in first cost than the alternative of constructing head sluices to the existing channels.

57. It will be observed that the levels on these, as well as on the other plans, have been referred to data furnished by local bench marks, and that different data have been adopted for the different sections of the work. This is in some respects inconvenient; but the inconvenience is not sufficient to justify the recasting of all the levels marked on the drawings. The height of the datum used, above mean sea level, has been marked on each sheet.

58. It is also to be noted that the detailed drawings of the regulating sluices do not show the levels of the proposed works either with regard to the assumed datum or to the existing works, and this point will need careful consideration when the project comes to be carried out.

59. From the mouth of the tunnel to the junction of the Sooroolly with the Vigay is about 46 miles, and for a further distance of 40 miles the Periar water is conveyed by the latter river, no works being required in connection with it until it reaches the Peranny, at which the distribution works begin.

Distribution Works.

60. The plans of these works are numbered from 1 to 79.

Peranny anicut.

61. The Peranny anicut, shown on Plan No. I, is a substantial structure requiring but little improvement; the only alterations proposed are the closing of the existing under sluice, the levelling of the crest of 5 above the floor of the latter, and some slight additions to the wing walls, apron, and adjacent embankment.

Main channel.

62. The line proposed for the channel is shown in survey and section on drawings Nos. 2 to 15, on which are also marked the points at which the various branch channels take off, and the position of the subsidiary masonry works shown in detail on drawings Nos. 16 to 79. The height above mean sea level of the data used on the different sheets have been added as explained above (para. 57).

63. Two lines are shown on the survey on drawing No. 2: the one proposed for adoption is that shown by the dotted line, the sections of which are given on No. 3; the other line involves a heavy cutting, and considered both by Mr. Smith and Major Oakes to be inferior to that proposed for adoption.

64. The channel is carried as close as possible to the foot of the Sirumullay and Allighiry hills in order to command as large an area as possible for irrigation. It crosses the drainage from the southern slopes of these hills, ample provision for the passage of which has been made, and is hence a costly work.

Branch channels.

65. There will be but little direct irrigation from the main channel, the distribution of the water being chiefly effected by the 12 branches shown in drawings Nos. 16 to 32; these branches will be carried along the ridges of the southern slopes of the Allighiry and Sirumullay hills in order that they may irrigate on both sides of these ridges, and be as little exposed as possible to injury from cross drainage.

66. These branch channels all terminate in natural drainage channels, and have regulating works at their tails where necessary where they skirt tanks to carry a supply to tanks lower down which are now fed by those above them; the latter are as a rule to be abandoned, and their beds to be cultivated.

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67. The following are the quantities of water carried by the main channel, and the areas for the irrigation of which the branch channels are designed :—

		Cubic feet per second carried by main channel with a depth of 6 feet.	Acres irrigated by branch channel.
First	Reach.	1,500	3,200
Second	„	1,440	2,500
Third	„	1,398	3,700
Fourth	„	1,275	9,400
Fifth	„	1,087	2,400
Sixth	„	1,036	1,600
Seventh	„	1,003	700
Eighth	„	990	2,100
Ninth	„	948	15,300
Tenth	„	651	14,100
Eleventh	„	385	5,000
Twelfth	„	288	15,000
			75,000

Head sluice and regulator.

68. The existing "Vadacurray" or northern channel taken off from the Peranny anicut has an open head to which it is proposed to put a head sluice of 20 vents, all of 5½′ span. The details of these works are shown on Plans 33 and 34.

69. The channel itself is also to be enlarged as shown on Plan No. 1 to carry the Periar water in addition to the present Vigay supply.

70. At 1,460 feet from the head sluice the main Periar channel will take off from the Vadacurray channel. Plan No. 35 shows the regulator sluices by which the supply is to be distributed between the two channels.

That for the Periar channel has 14 vents of 6′ span, and is calculated to carry 15,00 cubic feet per second with a depth of 6 feet on its sill. That for the existing channel has 7 vents of 6 feet 2 inches.

71. Although this regulator is so near the head sluice it is necessary that both should be built, as the ground between the two is unfavourable for the construction of a new channel. The existing channel hugs the river bank, and has frequently breached into the river, an accident, the recurrence of which will be prevented by the construction of the head sluice.

Regulators.

72. The details of the sluices and regulators for the supply of the branch channels and of the sluices for the distribution of water from them; are shown on drawings 36 to 44, reference to which is made on the longitudinal sections of the channels.

Falls.

73. The steepness of the Vigay valley necessitates the construction of numerous drops in both the main and branch channels. The details of these falls are shown in drawings Nos. 45 to 51. In two cases (Nos. 45 and 48) they are combined with bridges with a roadway of 9 feet in width.

Cross drainage works.

74. The designs of the various works for the passage of cross drainage across the channels are shown on drawings Nos. 51 to 68. There are in all the main channel 26 inlets and 32 outlets, six culverts, two acqueducts, two acqueducts and culverts combined, and three inverted syphons, besides two surplus sluices for tanks passed through by it, and 29 culverts on the branch channels.

Bridges.

75. Crossing the main channel, 12 bridges, and for crossing the branch channels 13 road tunnels are provided, addition to the combined falls and bridges referred to in in paragraph 73. The designs of the former are shown on drawings Nos. 69 to 75 and of the latter in Nos. 76 to 79. A bridge is also provided for carrying the South Indian Railway across the main channel in the 7th mile.

Minor distributaries.

76. The estimates provide for a total length of 102 miles of minor distributaries, in addition to the 38 miles of main channel and 93 miles of branch channel laid down on the surveys.

Period occupied in construction.

77. The working season in the Periar valley is from the burst of the south-west monsoon in June to the end of February, and as the few days of June which will be available for work will usually be absorbed in the collection of labour and preliminary arrangements for the season's work, the net working time is taken at eight months of 25 days each, or 200 working days in all.

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78. The head works are estimated to occupy five seasons in construction, besides one of preliminary work, which will be taken up by the construction of the road and laying out of the buildings, clearing of ground and similar matters.

79. The cuttings of the escape culverts and the erection of machinery will be taken in hand immediately on the opening of the following season, and during August and September, when the discharge of the river is small, the temporary dams will be constructed. By October of this season it is expected that the actual construction of the main dam will be begun.

80. The execution of the watershed and distribution works will be spread uniformly over the whole five seasons.

Discussion of details.

81. The ground upon which the various arrangements are based, and the data for the estimates of costs, may now be considered.

Choice of site.

82. The surveys show clearly enough that there is no site above the chosen which can in any way be compared to it; it is also known that there is no depression in the watershed ridge lower than that at the Goodaloor ghât head, while the fall of the river below the site chosen is exceedingly rapid (25 feet per mile), and it turns away in a north-westerly direction, thus diverging from the watershed ridge.

83. The rock, both in the river bed and on the watershed ridge, is a hard Sienite, free from fissures, and suitable both as a foundation for the dam and as a material for its construction.

Relative levels of dam, escape, and cutting.

84. The levels of escape crest and cutting sill are the same as those provided in Mr. Smith's project, which are the most suitable, taking all points into consideration, whether the dam be of earth or masonry.

85. In order to store the same amount of water between the sill of the cutting and the crest of the escape, the relative levels would have to be:—

Cutting sill.	Escape.	Top of dam.
0	115	130
25	116	131
50	120	135
75	127	141
100	137	150
110	142	154
120	148	159
130	155	166

and the total cost of the head works (exclusive of establishment) would be in round numbers:—

Cutting sill.	R
0	38,38,000
25	35,94,000
50	32,13,003
75	29,14,000
109	27,85,000
110	27,60,000
120	27,76,000
130	28,34,000

86. There is very little variation in the total cost between the 100 and 120-foot levels; the level chosen is, on the whole, the most economical, and has the additional advantage that it gives a length of tunnel and content of dam which can conveniently be executed in the same time without the use of shafts for the former.

Material of dam.

87. Most modern dams of any magnitude have been built of uncoursed rubble masonry. Concrete is nothing more than uncoursed rubble reduced to its simplest form; as regards resistance to crushing or to percolation the value of the two materials is identical, unless it be considered as a point in favour of concrete that it must be solid, while rubble may, if the supervision be defective, contain void spaces not filled with mortar.

88. The selection between the two depends entirely on their relative cost; on many cases, probably in the majority, the cost of preparing the stone and of mixing and laying the concrete exceeds that of building the rubble, the quantities of materials in both being practically identical.

89. At the Periar, however, skilled labour is abnormally expensive and difficult to procure in large quantities, while the facilities for the use of labour-saving machinery, which can be largely used in the manufacture of concrete, are unusually great.

90. On this ground, after full discussion, it has been decided to adopt the latter material.

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Quality of lime.

91. The quality of the lime to be used is shown by the following analyses of four different samples :—

		No. 1.	No. 2.	No. 3.	No. 4.
Moisture, &c.	P. C.	2·050	1·250	1·700	1·300
Sand and silica	„	32·750	22·550	20·500	25·100
Ferric oxide	„	2·400	2·400	2·600	2·000
Alumina	„	1·200	1·400	0·200	2·400
Carbonic acid	„	23·950	29·650	29·250	31·750
Sulphuric acid	„	traces	traces	traces	traces
Lime	„	24·200	40·096	42·400	35·000
Magnesia	„	11·460	1·153	1·586	1·713
Loss and unaccounted for	„	1·790	1·701	1·764	0·740
		100·000	100·000	100·000	100·000

92. These analyses indicate an "eminently hydraulic" lime, approaching the limit of an hydraulic cement; the composition differs very slightly from that of the well-known "Theil" lime, with which all the large dams in the neighbourhood of St. Etienne have been built, and which has also been used in the concrete blocks for the Suez and Port Said harbour works.

93. Experiments are at present wanting to show the actual resistance to crushing of mortar made with this lime; but it is considered that a limit equal to that allowed in the French dams may fairly be accepted, the quality of the material being fully equal to that employed in the latter.

94. The principle on which the pressures on the rear slope are calculated forms the subject of a separate note; calculated on this principle, the Ban dam has a maximum pressure of 17,985lbs on the square foot and the La Terrase 19,783lbs I have not been able to obtain a section of the Fureus dam in sufficient detail to enable the pressure to be accurately calculated, but it is about the same as in the Ban, or about 18,000lbs on the square foot.

Limit of pressure allowed.

95. The section designed by Rankine in his memorandum in connection with the Bombay Water Works would have a maximum pressure of 22,058lbs.

Conditions which the section has been designed to fulfil. (See Sheet No. 4 and Table I.)

96. It is considered, therefore, that the limit of 18,000lbs, may safely be adopted, and the section has been designed to fulfil the following conditions :—

1st.—That the lines of pressure shall always fall within the middle third of the dam.

2nd.—That the pressure on neither face shall exceed 18,000lbs on the square foot.

97. With the reservoir entirely empty, there will be at a trifling excess of pressure on the front face; but this case will not occur in practice, as the water level will never fall below 113′ above the river bed, and it will be seen that the conditions would be fulfilled, even were it 28′ lower than this. During construction, the water level will be raised to 90′ or 100′ before the upper 30′ of the dam is built.

98. The quantities have been estimated on the supposition that every hundred cubic feet of concrete will require 60 cubic feet of solid stone *plus* ten per cent. for wastage, 25 cubic feet of unslaked lime, and 30 cubic feet of sand.

Proportions of materials.

99. The two latter materials will make forty-five cubic feet of mortar, so that the allowances are rather in excess of what will be wanted in practice. In other words, the quantities named will make rather more than one 100 cubic feet of concrete.

100. Excellent sand is procurable from the bed of the river in numerous places above the dam; soorkee is not required, the lime being naturally hydraulic.

101. In the Ban dam every 100 cubic feet of masonry required fifty-eight cubic feet of stone and forty-two of mortar, the latter being composed of 37·8 cubic feet of sand and 891 lbs of lime; the bulk of the latter is not stated, but it could hardly have weighed less than 50 lbs per cubic foot which would give 18 cubic feet per 100′ of masonry.

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102. The section of the escape dam on the left bank is designed so that the lines of pressure shall be within the middle third of the dam when a depth of 12′ is passing over its crest, and that the water passing over shall have a clear fall to the surface of the water cushion below. The pressures on this dam have not been worked out in detail, as they possess no interest; the actual maximum pressure is about 9,000 lbs on the square foot.

Escape dam on left bank. (See Sheet No. 4 and Table II.)

103. At a distance of 60′ from the upper escape dam is another dam 10′ in height, with its crest 30′ below that of the former; the depth passing over this dam will be about one-and-a-half that passing over the upper one, so that the fall from surface to surface will vary from 30′ to 24′, and the depth of the water cushion from 10′ to 28′, the depths required by the common formula.

Water cushion.

$x = \sqrt[3]{H}\sqrt{d}$ being from 0 to 11·22 feet.

104. The material of the dams will be the same as that of the main dam, and no special coping will be provided, it being believed that a homogeneous material such as concrete, provided the upper surface be smoothly plastered, is much better capable of resisting the disruptive action of flowing water than any construction of detached stones, however carefully cemented or jointed together.

Material of escape dams.

105. The manufacture of the concrete will be entirely done by machinery, the materials not being handled from the time they are put into the trucks in which they are conveyed to the workshops until they are deposited in the dam.

Manufacture of concrete.

106. As far as the information now available extends, the best form of grinding machine is that made by Messrs. Jordan and Co., which has the advantage of combining the grinding and sifting in one operation. It is proposed therefore to use (subject to modification hereafter, if necessary) these machines for grinding the lime, which will be conveyed from them to hoppers, from which it will be measured together with the sand, into mortar mixers of the kind described at page 199 of "Gillmore on Cements, &c.," and, in other places, as having been used in the Paris improvement works.

Lime mills and mortar mixers.

107. From the mixer the mortar will pass direct into the hopper of the concrete mixer, which will be of the continuously revolving class (either Ridley's or Reynold's), where it will meet the stone also measured automatically in the required proportions.

Concrete mixers.

108. The measurers for the broken stone, sand, and lime, will be directly connected, so that the materials must always be delivered in the same proportions, and the mixed mortar must of course pass out of the mixer at the same rate as the raw materials pass in. The arrangement of these measurers is shown in detail on sheet No. 7, and their connection with one another on sheets Nos. 5 and 6.

Measuring apparatus for materials.

109. The stone will be broken by Blake's stone breakers placed immediately above the concrete mixers, so that it can pass directly from one to the other.

Stone breakers.

110. From the mouth of the mixers the concrete will be conveyed by ordinary elevators to the wire tramways by which it is conveyed to the dam; each bucket of the elevator contains the quantity required for one tramway bucket, and the two will be speeded to run at the same rate,* while a simple automatic arrangement will cause each tramway bucket to pasue when it reaches the elevator and continue its journey when filled.

Delivery of concrete to them.

*i. e., to pass the same number of buckets in a given time.

111. There are two wire tramways, the position of which will be varied from time to time as the work proceeds; during the construction of the lower portion, which is broad and short, they will run side by side along the whole length of the dam; for the upper portion they will run end to end, each serving one-half of the length of the dam.

112. The general arrangement of the concrete-making machinery is shewn on sheet No. 5 and details on sheets 6 and 7, while the arrangement of the wire tramways at different periods is shown on sheet No. 8.

These tramways will be further utilized for bringing the raw materials to the work-sheds as explained below, paragraph 221.

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113. From the tramways the concrete will be delivered to the depositing apparatus shown on sheet No. 9; this apparatus consists, first, of a light platform on which run trucks for the conveyance of the concrete from the tramways to any required point, and, secondly, of mechanism for ramming the concrete when deposited.

Depositing and ramming apparatus.

114. The latter mechanism consists of a light truck running backwards and forwards on the main platform and carrying a shaft on which are four stamps, each weighing 80lbs and having a fall of 18″. The stamps are driven from the cross shaft by cranks in the manner shown, which is preferable to lifting them by cams and allowing them to fall by gravity only, the spring between the stamp head and the link on which it is carried performing the two-fold office of increasing the speed of the blow and of allowing the crank to complete its revolution in spite of irregularities in the surface being stamped.

115. The length of the carrying link is adjustable to allow of surfaces being rammed at any depth from 6 feet to 9 feet below the cross shaft.

116. A worm on the longitudinal shaft acts upon one of the carrying axles of the truck, so as to cause the latter to advance a distance of one-fifth of a foot at each revolution of the former, and the direction of the revolution, and consequently of the movement of the truck may be reversed either automatically at any point required, or at the will of the attendant, so as to limit the range of movement of the truck and the stampers which it carries.

117. At each reversal of the movement the main platform on which the stamper truck runs advances longitudinally one-fifth of a foot.

118. If n be the number of revolutions per minute, b the width rammed (*i. e.*, transverses travel of the stamper truck), the number of reversals per minute will be $\frac{n}{5b}$ and the longitudinal distance advanced will be $\frac{n}{25}b$ per minute or $\frac{24n}{b}$ per day of ten hours, and the area rammed will be $24\,n$ in square feet.

This, with a speed for the cross shaft of 150 revolutions per minute, will give an area rammed of 2,600 square feet per day.

119. Each revolution of the cross shaft gives four blows from the stampers, so that the total number of blows delivered at the above speed will be 360,000, and as each stamper head has an area of one-fourth of a square foot, every portion of the area rammed will receive $\frac{360,000}{4\times3,600}=25$ blows.

120. The cross shaft will be driven by bevel gear from a longitudinal shaft, the latter being driven by a small steam engine. It might be driven by an endless rope from the turbine which drives the machinery, but the arrangement would be complicated and troublesome, and as the power required is only about five horse power, the cost of steam will be very trifling.

121. The arrangement of the framing is shown in detail on sheet No. 9; it is considered desirable to avoid the use of ties in the front face of the lower portion of the dam, as they would be expensive if left in the work; while, if drawn out, they would leave holes into which water might percolate, and (under a pressure of a 100 feet and more) do damage.

Framing.

122. The wrought iron strap corbels will afford sufficient support while the concrete is in process of setting, except where the ramming is actually going on, and there the additional support is provided by the attachment to the ramming machine itself.

123. It is not considered desirable to bring the weight of the ramming machine upon these corbels in the absence of cross ties, and the design is such as to obviate the necessity for this.

124. In the rear slope and in the upper 40 feet of the dam, where the water pressure is comparatively small, the use of ties is not so objectionable, and the simpler arrangements shown can be adopted.

125. The iron corbels will be useful for the attachment of scaffolding for future repairs, and are preferred to stone on account of their lightness; it is considered desirable to avoid the necessity for handling heavy weights, or for making large holes in the concrete framing.

126. The position chosen for the main workshops is such as to enable the whole of the machines to be driven directly from a horizontal shaft, itself driven by bevel gearing from the turbine.

Position of machinery.

127. An alternative arrangement would be to place the machinery at a higher level (about 130 feet above datum would be the best) and to drive the main shaft by a wire rope from the turbine.

128. But the advantage of this arrangement would be limited to the reduction of the distance between the work-sheds and the escape from which the greater part of the stone is brought, while it would have the disadvantage of risk of interruption by breakage of the rope, and a certain amount of loss of power.

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129. The total length of tramway required, and the power required to drive it, is the same in both cases, while the power required for lifting the concrete from the machines to the top of the work varies from nothing during the first two seasons to about five horse power during the last, an amount insignificant in itself, and a mere fraction of the reserve-power which we shall then have at command.

Driving power for machinery.

130. The circumstances so obviously enjoin the use of water-power that a discussion upon the point seems unnecessary, but it may be worth while to state briefly the relative cost of water and steam for the two hundred horse power which are required at the damsite.

	₹
The cost of the former is—	
Turbinel shafting, &c.	15,000
Repairs and maintenance	6,000
Labour	3,000
Culverts and regulating gear	14,000
	38,000
From which has to be deducted the value of a hundred and sixteen thousand cubic feet of stone or	8,700
Making the net cost	29,300
Or ₹146⅓ per horse-power.	
For steam the cost would be as follows:—	
One twenty H. P. portable engine	7,500
Repairs and maintenance	2,500
Belting, &c., for connection with machinery	1,500
Fuel, lubrication and water-supply	6,500
Attendance	2,000
Total per thirty net horse power	20,000
Or ₹667 per horse power.	

131. A single fixed engine would be rather more economical as to first cost, fuel and attendance, but the cost of setting and foundations would be very great, and for many reasons, if the steam were used at all, it would certainly be in the form of a number of portable engines rather than of a single stationary one.

132. The difference between the cost of steam and that of water would thus be not less than ₹94,000, while the latter has the additional advantage of being capable of increase fully thirty per cent. if required at a merely nominal expense.

Length of escapes.

133. The length of the right bank escape is fixed by the quantity of stone required for the dam; the total quantity required is 3,600,000 cubic feet, of which 1,400,000 are brought from the watershed cuttings, the cost of conveyance being less than that of quarrying at dam site; about 600,000 cubic feet is obtainable from the temporary escape cuttings, from the foundation trenches, the left bank escape, and from boulders and loose rock removed in clearing the ground, leaving a balance of 1,600,000 cubic feet to be obtained from the right bank escape.

134. The length required to give this quantity is about 420,′ making with the escape on the left bank a total length of 920′.

Rise of water above escape crest.

135. In the table No. IV. showing the rise of the lake surface during an excessive flood, the length of escape is taken at 900 only, and it is there shown that such a flood as that contemplated would raise the water level to 153·15′, while it would take nearly three times the discharges in given periods to raise it to 155′.

136. The discharges shown in this table are those of a flood that actually occurred in November 1869, and there is certain evidence that no flood approaching it in magnitude could have taken place for 50 years at least.

137. It may be accepted as certain that these discharges can never be exceeded by more than a very small percentage if at all. The level of 155′ has therefore been taken as the maximum for which the dimensions of the dam are calculated.

Method of disposing of water during construction.

138. The method of disposing of the water of the river during construction has been the subject of much discussion, and as there has been some misunderstanding as to the objects to be attained by the temporary escapes, it seems desirable to consider somewhat at length what these objects really are.

139. In an earthen dam it is essential that under no circumstances whatever shall a drop of water ever pass over the top of the dam, and, given the discharge of the river and the rate at which the work can proceed, the area of escape necessary is a matter of direct calculation.

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140. In the case of a masonry dam, however, the conditions are entirely different; it is necessary that the water should be diverted so as to allow the bed to be laid bare and the foundations properly put in; but for this, which can, if required, be done at a dry time, a very small area of escape culvert is required, and, when once the foundations are fairly in, there is no *necessity* for diverting the river at all. It is only necessary to screen off the particular portion of the dam which happens to be still unset, and the water may be allowed to pass freely over the remainder. As a fact, many dams both in Europe and in India have been constructed in this manner.

141. The passing of the water under rather than over the dam is purely a matter of convenience and economy—convenience as avoiding too frequent interruptions, and economy because it may very well be that the constant shifting of frames and protective apparatus will actually cost more than an escape culvert of moderate size.

142. It is obvious, then, that no comparison of the areas of culvert required for a masonry dam and for one of earth has any value; for the latter we must spend whatever sum may be necessary to prevent all chance of its being submerged, for the latter it would be folly to spend a couple of lakhs of rupees to prevent a submersion which may possibly cost a thousand.

143. It is evidently impossible to fix with anything approaching mathematical precision what is the particular area of escape culvert which will give the right degree of protection without undue expense; the principle on which the dimensions actually proposed have been arrived at is that the culverts should be capable of passing without submersion of the work, all discharges of which we have records in any months except July and November, that is, that the possible interruptions should be confined to those two months, and that the velocity through the culverts shall not exceed twenty feet per second.

144. The area of culvert necessary to fulfil these conditions depends upon the amount of storage available between the top of the temporary dam and the level at which the water is maintained during ordinary times, as it is the difference between this amount and the maximum discharge of the river during any given period which the culverts must pass.

145. With a given level of temporary dam, we can by lowering the normal water level, reduce the area of the escape culverts; but at the same time we reduce the head available for working the turbines, and increase the cost of the latter, or *vice versâ*.

146. On the other hand, by raising the temporary dam, we can save on the turbines or escape culverts, or on both, by lowering it we reverse the process.

147. The following table shows approximately (allowing for the value of stone) the cost of the temporary dams, escape culverts, and turbines for various levels :—

Height of temporary dam,	20	25	30	35	40
Normal level of water above dam. 10	64,000	67,000	69,000	71,000	75,000
15	51,000	53,000	55,000	57,000	61,000
20		49,000	51,000	54,000	57,000
25			48,000	50,000	53,000
30				50,000	53,000
35					53,000

There is very little difference in cost among the levels from 20′ to 40′; those chosen, 30′ and 25′, are preferred not so much as being the most economical, as because they are on the whole the most convenient for practical working.

148. In order to pass all discharges, of which we have records, with these levels, the total area required is about 230 square feet; the area provided is 240.

149. With the limiting velocity of 20′ per second, these culverts will discharge 4,800 cubic feet per second; in the three years of which we have records, there were altogether 30 occasions, of which 16 were in November and 6 in July, on which the discharge of the river exceeded this amount; on 16 of these occasions the discharge lasted only for a few hours, and would not seriously raise the water level above the dam; the effect of the remainder is shown in detail in Table VI.

150. It will be seen from this table that, with the area of culvert adopted, there were altogether three occasions, extending over six days, on which the work would be topped during the first season, four during the second, two during the third, and one during the fourth.

151. During the fifth season no flood that has ever occurred could top the work, because that season the saddle on the left bank will be available for the discharge of surplus, and in the fourth season none except the great flood of November 1869.

152. Assuming that the three seasons of which we have records represent a fair average, we may expect to be interrupted three times during November of the first season, twice during the second, and possibly once or twice during the third, with a remote chance of an interruption in the fourth.

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153. The table also shows that an increase in the area of culvert from 240 to 400 square feet would only save five out of the total of ten interruptions entered, while a reduction to 200′ would increase the number to 15.

154. To prevent such a flood as that of November 1869 from passing over the work even during the third season would require an area of 2,700 square feet, the cost of which would be out of all proportion to any possible damage that could occur from the submersion of the work for a few hours.

155. On the whole, the area chosen appears to form the most reasonable compromise between undue risk of inconvenience and loss by the interruption of work and undue expenditure on insurance against such risk.

156. It is obvious that, in order to limit the velocity through the culvert, we must either have the means of completely controlling the entrance of water thereto, or make its area so great as to limit the rise to the extent necessary for generating that velocity.

157. In Mr. Smith's design the tunnel mouth was uncontrolled, and with the area given of 1,064 square feet, a velocity of 45′ per second would be generated during a flood such as that of November 1869. To keep down to the lower limit of 20′ here proposed, an area of some 6,000 square feet would be necessary.

158. It is to meet this difficulty that the equilibrium shutters shown on sheets 10 and 11 have been designed. The pressure of the water is taken entirely by the ties connecting the shutters which are adjusted so as not quite to touch the faces of the frames against which they work; there is thus no friction, and only the weight of the shutter has to be moved.

159. In order to reduce this weight, four wrought-iron pipes 30 inches in diameter and $\frac{1}{4}$ of an inch thick are introduced, the buoyancy of which is very nearly enough to cause the whole gate to float; the actual downward tendency is about 400 lbs, and this is all that has to be moved in order to open the gate.

160. There is nothing in the whole construction different in kind from the work in an ordinary steam boiler, and there is no more difficulty in making the whole apparatus water-tight under a pressure of 60lbs on the square inch than in making a locomotive boiler steam-tight under double that pressure; but in order to provide against any leakage into the pipes (which would increase the weight to be moved), screw plugs are provided, which may be removed from time to time, the gates being let down for the purpose, and any water that may have leaked in may then be pumped out.

161. The tension on the tie rods is 5,303lbs per square inch under a 150′ of water.

162. The shutters will be adjusted so as to have a clearance of $\frac{1}{8}$ of an inch between themselves and the frames at the culvert mouth, and, to prevent leakage through this space when the work is completed, the frames shown in detail on sheet 11 will be introduced. By means of these frames a strip of vulcanised India rubber will be screwed tightly over the opening, and the passage of water completely prevented.

163. An incidental advantage of this form of gate is that it may be used to allow the passage of water into the river below the dam, if at any time such passage should become necessary, either in order that the water may be used there, or that the lake may be emptied.

Construction of culvert.

164. The entrance to the culvert up to 20′ from the face of the main dam is formed by tunnelling through the solid rock, as it is thought that there will be less chance of percolation through the rock than through the concrete if an open cutting were made and arched over; the cost is about the same.

165. It is for this portion only that the velocity of 20′ per second is adopted; for the remainder of the length the total area is 412 square feet, and the velocity is 9·32′ per second.

166. This latter portion is simply an open cutting 16′ wide covered by an arch with a radius of 20′ (forming an arc of 53°), and a depth at the side of 6′.

Pressures on rear face of dam due to culvert.

167. The support is removed from under the dam where the culvert comes in, and the pressure on the material has to be borne by the adjacent portions.

168. The width of the cuttings is 16′ and the extra pressure may be considered to be distributed over a similar distance on each side and over half the depth of the arch at the abutments, in other words the pressure due to 48′ has to be borne by 38, and the maximum pressure will be $\frac{48}{38} \times 12{,}741 = 16{,}094$ pounds on the square foot, the limit allowable being 18,000lbs.

169. The peculiar form adopted for the entrance tunnels is rendered necessary by the

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steepness of the rock on this side which prevents the use of the simpler and cheaper form adopted on the right bank (see below, paragraph 186, and sheet 13).

Fitting of frames.

170. The excavation of the mouth of each culvert will be made a little in excess of the standard dimensions so as to allow of the easy fitting of the iron face frames; the gates will be lowered into position and the frames set up at the right distance from them, the space between the latter and the rock being then packed in with fine mortar of lime and sand in equal quantities.

Gearing for shutters.

171. The gearing for working the gates is shown in detail on sheet 10.

The gate is carried at one end of a beam 30 in length working on a pivot at the other end.

Attached to a point 10′ from the pivot end is a chain connected to a buoy of sufficient floating power to lift the gate. The length of this chain is adjustable at pleasure so as to give the opening necessary to pass the normal discharge of the river at any level at which it may be desired to retain the water surface; an increased discharge raises the water level and increases the opening; a diminished discharge has the opposite effect.

172. It is necessary to prevent the gate from rising to a height sufficient to generate velocity exceeding 20′ per second, whatever be the head on the front face.

The buoy A carries a light chain coiled round a drum B fixed to the bottom of the cutting; connected with the drum B is a drum C with a diameter $\frac{3}{10}$ths that of B, round which is coiled a chain passing over the pulley D and attached to the axle and rollers E; as the water rises, the rollers are drawn along by the chain between the beam FG and the lifting lever, and the travel of the latter is limited by the position of the rollers; as the water falls, the rollers are drawn back by the weight H.

173. The inclination and position of the beam FG is found by calculation, and is such that the maximum possible lift of the gate for any water level is $\frac{32}{\sqrt{n}}h$, being the difference between the water levels above and below the dam; with a velocity equal to $5\sqrt{h}$ the discharge will therefore be 1,920 cubic feet per second for each culvert.

174. This is the maximum discharge possible; below this limit the discharge is regulated entirely by the level of the lake; the main lifting buoy is of course submerged when the regulating gear comes into play.

175. The form given to the guiding beam FG gives correct results for depths 30′, 50′, 90′, and 130′; for intermediate levels the results are not quite accurate as the face should have a slight curve instead of being a straight line, but the error nowhere amounts to more than three per cent.

176. If a greater velocity than 20′ per second be considered permissible, the inclination of the beam FG can be altered accordingly; but it would be unadvisable to make any reduction in the area of the sluices, as the head necessary to give this velocity is nearly as much as it is convenient to allow during the early part of the work; the extra velocity should be used to give additional discharge and reduce the risk of submersion.

Temporary dam.

177. The following mode of construction will be adopted for the portion of the temporary dam which is within the ordinary water spread of the river. Cases 18′ by 5′ by 10′ internal dimensions will be sunk in the bed of the river at intervals of 15′ from centre to centre, and kept in position by iron rods jumped into the rock at their four corners; they will be made as water-tight as possible, and the interior will be pumped dry, and the lower part of each buttress and of the wall attached to it constructed inside them, the full height being completed in the ordinary way. A groove 6″ broad and 1′ deep will be left in each side of each buttress at 6′ from the front face; there will then be a series of eighteen piers 5′ wide with openings 10′ wide between them, extending across the river bed. Nine of these openings will be closed by shutters 10′ high let down in front of the buttresses and in the grooves in their sides, and the spaces thus enclosed built up to 5′; the shutters will then be removed and the other nine openings built up in the same way to 10′; then the first nine to 15′ and so on, until the whole stream is carried by the escape culverts.

178. The discharge of the river during August and September rarely exceeds 12,000 cubic feet per second, which the 90′ of opening always left will pass with a depth of about 3′, so that the work will not be liable to much interruption.

179. The lower dam will not be begun till the upper one is finished and being constructed in practically still water will be an easy job.

180. When the lower dam is completed, the space between the two dams will be pumped dry, and the foundations of the main dam put in.

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181. No point connected with the permanent escapes calls for explanation beyond what has been already given, but it may be as well to state here that all blasting will be done with dynamite, electricty being used for firing the charges. All boring except in the water-shed tunnel will be done with hand-power drilling machines which give better returns for the labour employed than the ordinary jumper.

Permanent escape.

Sheet No. 12.)

182. The position and arrangement of the main workshops is shown on Sheet No. 5; the total power required for driving the machinery is about 200 horse power, which is provided by a single horizontal turbine. The position of various machines is arranged so that, as far as possible, equal powers shall be taken off on opposite sides of the main shaft, so as to reduce the strains upon the bearings.

Main workshops.

183. The level of the water surface above the dam will be from 25′ to 30′, and below it will be from four to eight feet as long as the temporary dams are not topped.

Turbines.

184. The head available for working the turbine has therefore been taken at 20′, and the quantity of water required will be 120 cubic feet per second, or less than two-thirds of the minimum discharge of the river.

185. The culverts for supplying the turbine have an aggregate area of 48 square feet, so that the velocity required is less than 3′ per second. Under ordinary circumstances the discharge through these culverts will be limited to the 120 cubic feet per second required for the turbine, but they will be available on an emergency for the discharge of 960 cubic feet.

186. With this view they will be furnished with gates similar to those of the main culvert, their weight being so adjusted that they will have a slight tendency to open instead of to close. This tendency will be counteracted under ordinary circumstances by a light chain passing along the culvert and attached to a buoy in the turbine pen-stock, so that, if the water in the latter falls below the required level, the gate will open, and *vice versâ*. If the culvert be required to discharge extra water, it is only necessary to let go the chain to the extent required to give the necessary opening. As this will only be done on rare occasions and under special orders, the extent of the opening can be limited as circumstances may require, and the regulating gear provided for the main culvert is unnecessary.

Supply culvert.

(Sheet No. 13.)

187. The watershed cutting is a work of an ordinary description, and requires no special notice; if the slope of the cutting and tunnel were the same, the latter should begin when the former reached the depth at which the cost per foot of advance was the same for both, which, with the dimensions and prices here adopted, would be 27′; but as the slope of the tunnel is greater than that of the cutting, the total length is diminished by reducing the proportion of the former, and it is economical to extend the cutting a little further, and the proper depth for the change becomes 30′ as adopted.

Watershed cutting.

(Sheet No. 14.)

188. The nominal area of the tunnel is 80 square feet; but to provide against slight irregularities in the excavation, an area of 84 square feet has been provided for. A heading of 42 square feet will be first excavated, and afterwards enlarged to the full area.

Watershed tunnel.

(Sheets Nos. 15 and 16.)

189. It would be convenient to work for any distance from the upper end of a tunnel with a slope of one in seventy-five, and only 350 feet of the whole length of 6,650′ will be thus done, the remainder or 900 days' work at 7′ per day being done from the lower end.

190. The boring for the heading for this 6,300′ will be done by machines driven by compressed air; it could be done somewhat cheaper by hand, but in this case we could not reckon on an advance of more than 2½′ and 3′ per day, and two shafts would be necessary, the cost of which would more than cover any saving in boring.

191. Four drills will be employed, and there is no doubt that the advance of 7′ per day, or 74 cubic feet for each drill, can easily be obtained. At the St. Gothard the advance with six drills was from 10′ to 12′ on a heading with an area of 67 square feet, or from 112 to 134 cubic feet per diem for each drill. The estimates of the daily work of the drills are very moderate as compared with actual experience both in Europe and America.

192. The boring for the enlargement of the principal tunnel and for the whole of that portion which is executed from the upper end will be done by hand. The heading will be kept only so far in advance of the enlargement as to prevent the workmen from interfering with one another as the firing of the charges for both will be done at the same time.

193. Artificial ventilation will probably be required after the first 3,000′, and provision has been made for the exhaustion of 6,000 cubic feet of air per minute. The amount of

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dynamite exploded daily will be about a 58lb. day, the gases generated by which will occupy about 20,000 cubic feet or about $\frac{1}{300}$ part of the fresh supply in 16 hours. About 2,000 cubic feet of air per day will also be supplied by the drilling machines. At the St. Gothard, where the consumption of dynamite was about 600lb per day, the drilling machines supplied 5,000,000 cubic feet of air per day, and the exhausters extracted 16,000 per minute.

194. About 40 horse power for 14 hours will be wanted for working the compressors, and 25 horse power for ten hours for driving the ghât wire tramway. It is proposed to obtain this power from the Muliapanjan, the stream up whose valley the Goodaloor Ghât runs. By a turbine placed near the mouth of the tunnel, we can easily get a head of 60', so that the quantity of water required will be 8 cubic feet per second.

195. This stream receives the drainage of a portion of the stream of the same name on the Travancore side of the watershed, which has been diverted into it by a dam at the point shown on the general survey, and certainly supplies more than the quantity required for six months of the season. During January and February it may fall short, and will be supplemented by steam-power, for which provision has been made in the estimate.

196. The average discharge of the stream during the whole season is considerably more than 8 cubic feet per second; and if a site could be found where some 30,000,000 of cubic feet could be stored at a rate not exceeding one rupee for 4,000 cubic feet, this would be more economical than to use steam, but the possibility is doubted.

197. It is not impossible that it may be found worth while to convey the whole of the power required for working the drills and ghât tramway by means of electricity from the Periar, where the extra power required can be provided at a small cost; but the information at present available as to the real cost of the electrical transmission of power is so vague that no reliance can be placed upon it.

198. The entry of water to the tunnel will be controlled by the gates shown on sheet No. 16; these gates are similar in principle to those already described for the escape culverts. They have an aggregate area of 120 square feet, that of the main tunnel being only 80. The reason of this is that if, as is not unlikely, the water-supply is found greater than is now anticipated, the main tunnel can be enlarged at small expense, but it would be awkward and inconvenient to enlarge the gates and entrance tunnels, which would necessitate not only sacrificing the original gates and frames, but also lowering the lake so as to leave the sill of the cutting exposed, which could not be done without opening the escape culverts under the dam.

Transport of materials.

199. The transport of materials is a very important item in the cost of the work, some 80 tons of limestone and the stores and food for the whole working party having to be transported daily from the lime quarries to the watershed up a ghât 1,200 feet in height, and some 45 tons of lime and stores, besides 1,500 cubic feet of stone, weighing upwards of 100 tons from the watershed to the site of the dam.

Various methods considered.

200. Estimates have been made with considerable care for all sorts of means of transport, including railways worked by locomotives and by ropes, wire tramways, ordinary road worked both by steam and by cattles and water transport; and it is found that, on the whole, the most satisfactory arrangements are those now to be explained.

201. The main line of road from Madras to Travancore, of which the Goodalur ghât forms a part, crosses the watershed close to the site of the proposed works, and then diverges to the west from the valley leading to the site of the dam, and cannot be used for transport beyond the watershed.

Traction engines from lime quarries to foot of ghât.

202. The lime quarries are situated at from 3 to 4 miles from the foot of the ghât, and the quantity of stone to be carried daily is about 80 tons; this can be carried from the quarries to the foot of the ghât by a single traction engine making 5 trips daily.

Objections to their use on ghât.

203. The use of traction engines on the ghât is objectionable on account of the great waste of power in working on a steep gradient, and the awkward turns and zigzags which occur in several places; the engines returning with the empty trucks could not run at their full speed of 8 miles an hour as they can on more level ground, and 4 miles an hour would probably be as much as would be safe. Although the ghât is only 4 miles in length, it is probable that three trips daily would be as much as the engines could do. The total weight to be carried daily including a small allowance for general stores is about 200,000lb; and as the engines intended to be employed, which on a level will take 60,000lb (exclusive of trucks) with ease, would not take more than 16 or 17,000 on an incline of 1 in 16°, four such engines would be necessary. The

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first cost of engines and wagons would be ₹12,000, repairs and maintenance ₹14,000, and working expenses ₹40,000; to which must be added ₹8,000 for the improvement of some of the worst turns in the road, and ₹10,000 (at ₹500 per mile for five years) for maintenance, as the allowance made by the Local Fund Board will certainly not keep the road in a condition to allow steam to be used economically.

204. The total cost of transport for this section would thus be about ₹1,14,000, a sum probably not much less than the cost of transport by ordinary carts, though there might be a difficulty in getting the latter in sufficient numbers.

Advantages of wire tramway.

205. It is therefore proposed to use a wire tramway, which for such a position possesses immense advantages. It can be worked with ease on a gradient of 1 in 4°, and can be laid so as to avoid all the zigzags necessary in a road, and thus effect a great saving in distance, while there is absolutely no *waste* of power caused by the incline, the difference between the power required to work a given length on a level and the same length on any gradient being simply that required to lift the net paying load the vertical height between the top and bottom of the line.

206. To show how great this waste is on an ordinary road, the 200,000lbs. of goods here in question would be carried over a level line of four miles in length with the greatest ease by a single light engine indicating 25 horse power, whereas for the same distance on an incline 1 in 16°, 4 engines of 40 horse power are required, showing an extra work of 135 horse power due to the incline alone, the actual difference in *useful* work being only $\frac{21,120}{16} \times \frac{200,000}{33,000 \times 600}$ or 13½ horse power for 10 hours, and this latter quantity with an addition of 25 per cent. for friction is all that has to be provided in a wire tramway on account of the rise.

207. The length of the existing ghât is a few feet over four miles; the distance from top to bottom as the crow flies is 10,400′; the length of tramway provided is 12,000′, which is rather more than will be required, as it can be laid very nearly in a straight line. The first cost of the tramway will be ₹30,000; carriage, erection, maintenance and working ₹26,000, while the power required will be about 30 horse power. This, as already explained, will be provided by the same turbine as works the air compressors for the watershed tunnel, and the share of its cost debitable to the ghât will be ₹4,000, making a total cost of ₹60,000 for the transport over this section.

Ghât to be used for heavy articles.

208. For articles too heavy to be carried by the wire tramway (or exceeding about 3 cwt.), the existing ghât road will be used; but the movement of such articles will be almost entirely confined to a few days at the beginning and end of each season.

209. Some saving in transport would be effected by burning the lime at the quarries instead of at the watershed as proposed, but it is considered that this is of less importance than the improvement in supervision effected by having the kilns above the ghât where they will be under the eye of one of the officers employed on the work.

Head of ghât to river.

210. From the head of the ghât to the site of the dam the superior economy of the wire tramway is less decided, as there is less room for saving either in distance or cost of working; and as some means of transport capable of conveying heavy weights must be constructed, the saving in the every day work by the use of the tramway does not justify its construction in addition to such other means. These other means are water, railway and road.

Water transport.

211. The first of these is undoubtedly the cheapest in every way, as by a series of dams in the Muliapanjan and Kythery valleys, it could be obtained at a cost less than that of a road, while as regards working expenses it would be decidedly cheaper; but it would be impossible to use it without interfering with the work in the southern cutting, and the idea has had, though reluctantly, to be abandoned.

Railway.

212. A light railway would cost in working about ₹40,000 less than the sum estimated for the road, but it would cost in construction and maintenance ₹60,000 more, and would probably be more liable to injury from accidental causes.

Road.

213. In Mr. Smith's original designs it was proposed to keep the road above the maximum water level of the lake, involving a length of more than 19 miles from the head of the ghât to the dam, but this is quite unnecessary, all that is wanted being that the road shall not be liable to submersion as long as it is required for use. After the completion of the work it will be useless and even before that time a portion of it will have been superseded by water carriage.

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Trace adopted.

214. The trace adopted is shown on the general survey and in more detail on Sheets Nos. 2, 14, 15, 17, 18 and 19.

Starting from the watershed at a level of 168 above datum, it falls at the rate of 1 in 150° for 4,500′, and then rises at 1 in 600° for 6,000′ keeping as close as possible to the side of the cutting. It runs level for 500′, and then rises at 1 in 600° to the saddle between the Muliapanjan and Nataman's valleys, which it crosses at 23,000′ from the watershed at a level of 143; after 200′ level it falls 1 in 60° to the Nataman's stream, which it crosses at 27,000′ on a level of 83, being about 21′ above the bed of the stream.

It is level from 26,800 to 27,800, and then rises at 1 in for 600° for 6,000 to the saddle above the junction of the Kythery and Nataman's valleys, which it crosses at a level of 93; a further distance of 6,200′ on a level completes the line.

215. The total distance from the head of the ghât to the works is 40,000′ or a little over 7½ miles, and it will be seen that the line is exceptionably favourable, there being no gradient against the traffic except 1 in 600°.

Traffic to be carried.

216. The works to be done during the first three seasons is the conveyance of 90,000lb of lime and stores from near the watershed to the site of the dam, a distance of 7½ miles, and of 1,300 cubic feet of stone, about weighing 210,000lb from the southern end of the watershed cutting, an average distance of about 6 miles.

217. Two engines of the class provided will do this with three trips each per day, one from the watershed and two from the cutting, the speed being from three and-a-half to four miles an hour loaded, and eight miles when returning with empty trucks.

Water transport to be used during the two last seasons.

218. During the two seasons the water level will be raised to about 60′ above datum, and the engines will only be required to carry the material to the point where the road crosses the Natamans's valley, from whence they will be conveyed in the boats to the dam. This shortens the distance to be run by about two miles, enabling the engines to make three trips daily instead of two from the cutting and to carry 1,900 cubic feet of stone instead of 1,300.

Total cost of transport.

219. The actual cost of transport, including all charges, amounts to three-fourths of a rupee per ton, or R5·35 per 100 cubic feet of stone, from the cutting to the dam site, the cost of excavation at the latter being R7·50 per 100 cubic feet.

220. From an economical point of view it would be advantageous to use in the dam the whole of the stone (about 1,600,000 cubic feet) excavated from the southern watershed cutting and adjacent portion of the tunnel, but it is not considered desirable to reduce the length of the escape below the 900′ provided for.

Distribution of materials at site of works.

221. On arrival at the dam the contents of road trucks will be conveyed to the main workshed by the wire tramway which is used for the distribution of the concrete, the buckets bringing material by the line being emptied, and then passing on to the other line to be filled with concrete. The materials will be distributed to the different machines by small trucks running on the two lines of rail shown on Sheet No. 5.

222. It may appear simpler to bring the road close down to the main workshops; but to do this would cause the former to cross the line of the dam at an inconveniently low level; and if it were brought to the workshops at the ground level, arrangements would have to be provided for lifting the materials as well as for their horizontal transfer, while it were raised so as to be above the level at which the materials must be delivered to the machines an awkward revetment would be required, and the wire tramway would have to be raised, and the cost of the elevators increased, in order to clear the road engines and wagons. Moreover, the arrangement adopted is the most convenient during the two last seasons, when the materials will be brought by water to the front of the dam, and lifted to the level of the wire tramway by a hoist worked by the rope itself.

223. The stone from the escape will be brought in trucks to the nearest point of the wire tramway, by which it will be conveyed to the workshops.

Buildings.

224. The general arrangement of the buildings is shown on Sheet No. 2, but it has not been considered necessary to prepare detailed plans for them, as such plans would certainly be modified in execution. It is intended that the buildings shall have walls of pise with thatched roofs, except the magazines which will have corrugated iron under the thatch.

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225. The designs of the regulating and distribution works call for no further explanation than has been already given; they are of an ordinary description, and, having been designed with great care by an officer of large experience, were reviewed and revised by Major Oakes when acting as Chief Engineer for Irrigation. They are in no way affected by the modifications introduced in the designs for the head works. Major Oakes' memorandum explaining the alterations made by him is attached to this report.

Regulating and distribution works.

226. The position of the rock at the dam site is the principal element which governs the quantities in the main dam and its subsidiary works. The measures adopted by Mr. Smith were such as to leave no doubt that the general outlines of the solid rock have been found with sufficient accuracy for all practical purposes; but to provide against local irregularities, which cannot be discovered until the whole site has been laid bare of earth, a slight addition has been made to the lengths of dam required at the different levels. The lengths marked on the longitudinal section on Sheet No. 3 are those which the surveys actually show, but in the estimates 10′ has been added to each length *plus* so much more as may be required to make up the next even ten; that is, if the actual width shown is 965′, the quantities have been calculated for 980.

Quantities.

227. In framing the estimates for the Head Works it has been found impossible to make any use of the experience gained as to the cost of similar work elsewhere, for even if the unusual scale of the work did not vitiate any conclusions drawn from such data, the latter would be valueless owing to the peculiar conditions to be satisfied and processes to be adopted. It may safely be said that so large a mass of concrete has never yet been executed anywhere, while in India at all events labour saving machinery has never been used to anything like the same extent.

Estimates.

228. The principal elements which go to make up the cost of work of this description—

1. Labour.	4. Transport.
2. Fuel.	5. Machinery.
3. Explosive.	6. Supervision.

Of these No. 1 is abhormally high, No. 2 abnormally low, Nos. 3 and 5 differ little from the normal rates, while No. 4 is unusually small for the principal material (the stone) which is ready close to the site of the works, and rather high for the line, though there are many cases in ordinary experience where lime has to be brought from distances greater than the fourteen miles with which we have to deal. The conditions for No. 6, which affects all the others, are unusually favourable, owing to the concentrated nature of the work.

No. 1 also enters much less and No. 5 much more into the calculation than is usual.

229. It thus becomes necessary for the estimates to be framed upon independent data based upon consideration of the actual quantity and cost of labour, material, plant, &c. required for each class of work.

Principle on which rates have been worked out.

230. These data are given in considerable detail, and need only a few words of explanation here.

231. The ordinary price for unskilled labour in the Periar valley is six annas per diem, so that for the 900 working days that the construction of the main dam is expected to occupy each cooly will cost R337½; to this one-third has been added to cover such incidental expenses as medicines, food of sick men, blankets, &c., making the total cost of a day's work eight annas or R450 for the whole period of 900 days. Hutting and petty supervision are provided for separately.

Cost of labour.

232. For feeding machinery and other special work picked coolies will be employed, and their pay is estimated at R600 for the whole period.

233. Head coolies are taken at R1 artizans (carpenters, blacksmiths, &c.) at R1½, foremen at R2 per day's work. The drivers of the traction engines are rated as foremen and the firemen as artizans.

234. The cost of fuel is taken at R1 for 900 pounds or R2½ per ton, which is certainly an over-estimate, as the experience of the Forest Department is that the more cutting and stacking does not cost more than R1 per ton, and the conditions are favourable for collecting and bringing it to the site of the dam. The total quantity required for the whole work will be about 45,000 tons, which would be supplied by 300 acres of orest, for about $\frac{1}{35}$th of the area of the lake.

235. The price of dynamite at any Indian port is R1-8 per pound to which has been added four annas for transport to the site of the works—an ample allowance even if, owing to the obstructiveness of some of the Indian Railways, cart transport should have to be adopted.

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236. The greatest pains have been taken to ascertain the actual cost and capacity of the machinery required, and it is believed that the estimates may be relied on as thoroughly accurate; except in one or two cases of special design the prices have been taken from price lists of well-known makers, two or three being compared in many cases; and in several instances, including the turbine, the wire tramways and the rock-boring machinery, the manufacturers have been written to for more detailed information, which has in all cases been fully supplied. The English prices including packing have been converted into rupees at ₹12 per £ sterling, and ₹100 per ton, added on account of freight, &c., made up as follows :—

Machinery.

	₹
Freight from England to Tuticorin and landing charges . .	65
124 miles of railway from Tuticorin to Ammianaikenoor . .	20
68 miles of road from Ammianaikenoor to the Periar . . .	15

237. Where the exact weight is not known, the cost of carriage has been taken at ₹3 per £ sterling of the English cost, which is found to be a fair average where the weights are known. Liberal allowances have been made for repairs and erection, the latter being but a small item in the majority of cases.

238. The whole of the stone used in the manufacture of concrete is obtained from one or other of the works for which separate estimates are framed, and it is more convenient to include its cost in these estimates. The rate for concrete is, therefore, exclusive of the cost of quarrying the stone, which is 7½ per 100 cubic feet of solid stone, or 5 per 100 cubic feet of concrete.

Cost of concrete.

239. Including this item the actual cost of concrete is ₹20 per 100 cubic feet, which covers the cost of all machinery directly employed in the excavation of the stone, transport of materials, and manufacture of concrete. The ordinary rate for concrete in the Madura district is from ₹15 to ₹17 per 100 cubic feet; but for the reasons given above little value can be attached to any comparison of rates.

240. Excluding establishment and indirect charges and payment to the Travancore Government, the total cost of the Head Works in the Periar valley is estimated at ₹19,50,000, being ₹4,17,460 less than the cost at which they were estimated by Mr. Smith, the saving being due entirely to the alteration in the material of the dam.

241. The rates of the regulating and distribution works need no comment. No alteration has been made in Mr. Smith's designs or estimates as revised by Major Oakes, but the latter have been re-written and classified in accordance with existing rules.

242. Under the head of preliminary expenditure ₹79,665 has been expended up to the end of 1881-82, and the balance of ₹35,335 provided in the estimates will amply suffice to cover any further expenditure that may be necessary.

Preliminary expenditure.

243. Under the head of "Land" is included a sum of ₹8,00,000 as compensation to the Travancore Government for the use of site of the works and for the water diverted. The actual amount payable under this head has not yet been settled, but it is believed that it cannot exceed the sum stated. More than a year ago the Government of Madras addressed that of Travancore, offering a sum of ₹6,00,000, but it is believed that no definite reply has yet been received.

Land.

244. A statement showing the actual cost of establishment required is included in the papers submitted herewith; but this (which amounts to ₹8,06,850) is of course a Provincial charge, the amount to be debited to the project being ₹9,25,000.

Establishment.

(Statement III.)

245. Provision is made in this statement for additional allowances to the officers and subordinates employed on the head works; these allowances which have always been given have hitherto taken the form of double travelling allowances *plus* a personal allowance, but the former appears objectionable as being opposed to the principle that travelling allowances should nto be looked to as a source of emolument; and this estimate provides for the following fixed allowances :—

	₹
Superintending Engineer	300
Executive Engineer	200
Assistant Engineer	100
Sub-Engineers	100
Supervisors	60
Overseers	30

Office and lower subordinate establishment—one-third of pay, with minimum of ₹15.

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246. Provision is also made for an allowance to an officer in England for superintending the purchase and preparation of machinery, which should, it is thought, be attended to by some one employed on, and interested in, the project. This charge is, it is considered, a legitimate addition to the 23 per cent. on works expenditure, as the latter is not charged against expenditure for machinery to be purchased in England. It amounts to less than five per cent. of the latter expenditure, and can be reduced if the officer employed should be on furlough at the time.

247. The establishment provided for the head works will be employed in the plains during the four non-working months, but what with sickness, privilege leave, and other contingencies it is not probable that their service during these periods will be of much value.

Tools and Plant. (Statement IV.)

248. The item of Tools and Plant includes all charges for such articles not directly debitable to the rates for different items of work, and is probably somewhat in excess, though not much so, of what will actually be required.

249. Mr. Smith's estimates included a sum of ₹55,950 for "Stationery" and "Office Furniture," but under present arrangements this does not appear to be a legitimate item, the former being properly an "Establishment" charge, and the latter being chargeable against "Tools and Plant."

Total of estimate.

250. The estimate attached is in the prescribed form; its total amount exclusive of interest is ₹65,01,663 distributed as follows :—

1. Direct charges.

	₹
Head Works	27,50,000
Regulating Works	3,30,000
Distribution Works	21,20,000
	52,00,000
Establishment	9,25,000
Tools and Plant	60,000
Total	61,85,000

2. Indirect charges.

Abatement of Land Revenue	85,413
Establishment	2,21,250
Total	3,06,663

Returns.

251. We have now to consider the returns to be obtained from this expenditure.

Observations of rainfall and discharge of river.

252. The observations of actual discharge of the Periar extend over only 3 years, and over 8 months of those years. The rainfall during the short period when both rainfall and discharge were gauged was found to be to the depth run off from the drainage area, as 1·80 to 1·00, a proportion which was maintained with a remarkable approach to uniformity.

Estimated rainfall and discharge.

253. The rainfall over the Periar catchment was estimated by Major Ryves, who had no direct observations to guide him, at 78·98 inches, but this estimate was merely a rough average of the fall at the following seven stations :—

Cochin	111·16
Trevandrum	65·01
Augustemully	191·02
Trimungulum	31·58
Madura	42·49
Meyloor	37·59
Tencausi	41·05

254. The last four of these are under climatic conditions so entirely different from those of the Periar valley that no inference can be drawn from their records; the remainder approach it more nearly, and Augustemully, which has the heaviest rainfall, nearest of all.

255. Table VII shows the rainfall as estimated, first, from an average of the falls at the three stations named, and second, as calculated from the recorded discharges. It seems clear

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from these figures that the estimate given in columns 5 and 8 of the following table (No. VIII) as to the total quantities of water available for irrigation are exceedingly moderate.

Revenue estimates.

256. The total quantity here entered is sufficient for the irrigation of more than 100,000 acres of first crop and 75,000 of second, and subject to this limit the question for consideration is what area is available for the utilisation of the water, and what rates can that land pay.

Mr. Clogstoun's report.

257. This point has been made the subject of a special investigation by an officer of the Revenue Settlement Department (Mr. H. T. Clogstoun); and as his conclusions, except upon one point, have been accepted as moderate by all the Revenue authorities concerned, they may be adopted as the basis of our present calculations.

258. Mr. Clogstoun's report is attached in full as it seems impossible to do justice to it by a mere abstract; his general conclusions are to the effect that a return may be looked for of ₹4,67,374 from a total area of 93,000 acres, equivalent in its demand for water to an area of 80,878 acres, in Government villages, of ₹91,260 from 15,210 acres of inam and zemindary land, and of ₹2,15,648 for a second crop from 53,912 acres, making a total return of ₹7,74,274 from an area of 150,000 acres of irrigation.

259. There is no doubt that these estimates are moderate except upon the one point of the second crop; as pointed out by the Director of Revenue Settlement in submitting Mr. Clogstoun's report, it is always doubtful what extent of land will be cultivated for a second crop, and that officer proposes to reduce the estimated return on this account from ₹2,15,648 to ₹1,00,000. This appears, however, to go too far in the opposite direction considering the known anxiety of the ryot to get as much as possible out of his land, and the absolute certainty (the absence of which is the chief cause of the uncertainty as to the extent of a second crop) that the water will be available.

Direct revenue anticipated.

260. The return on this account has therefore been estimated at ₹1,41,374, making a total of ₹7,00,000 as the expected return.

No indirect revenue.

261. In this total it must be borne in mind that no notice is taken of the sums to be realised by the sale of occupancy rights either of fresh land brought under cultivation, or of the beds of tanks to be abandoned, a source from which all the revenue authorities concerned are agreed that some return may be expected, though they differ as to its amount.

262. Neither has any credit been taken for indirect revenue on account of fresh land taken up in place of existing dry land converted into wet. It is notorious that, whenever this process takes place, fresh land is brought into cultivation to supply its place; and as the project is debited with the existing assessment of present cultivation, it ought to be credited with the revenue from new cultivation directly due to its operations; it is believed that this is in reality the meaning of the "indirect revenue" which figures so largely in the returns of the Northern Provinces.

263. As neither of the sources of revenue referred to in the two last paragraphs are capable of accurate estimate, they have been omitted altogether, the project being perfectly able to stand upon its direct financial results.

Financial results.

264. In the financial statements attached to this report the following assumptions are made:—

1st.—That the payment to the Travancore Government is made in two instalments of ₹4,00,000 each commencing with the year following the completion of the works.

2nd.—That the full development of the revenue occupies ten years, rising by annual increments of ₹70,000.

3rd.—That the maintenance charges amount to ₹75,000, and reach this amount in five years by annual increments of ₹15,000.

265. The net result is that the capital expenditure will ultimately amount to ₹77,07,683, and the net return to ₹5,74,600, being 7·76 per cent. on the capital.

Possible extension irrigation.

266. In the event of the water-supply proving larger than is anticipated, it can be utilized with advantage on the south bank of the Vigay. Surveys and estimates have already been made for the construction of channels to irrigate 40,000 acres of land (30,000 first crop and 10,000 second). These estimates amounted to ₹79,87,000, to which would have to be added ₹30,000 for enlarging the watershed tunnel, which with establishment and indirect charges would probably bring the cost to nearly ₹12,00,000. This is a sufficiently favourable result to justify the extension if the water-supply should turn out sufficient, but for the present the proposals are limited to those already described.

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APPENDIX I.

Note on the mode of calculating pressures in masonry dams.

Let ABCD (fig. 1) be the section of a dam and EF a line drawn from any point in the rear slope to a point in the front slope. Then the plane of which EF is the projection is acted upon by two forces: first, the weight of the portion of the dam above that plane; and second, the pressure of the water upon the front face AF.

Let the resultant of these two forces per unit of length be called R; and let its direction be GR cutting EF in H.

Let EF$=l$, EH$=u$ and the angle GHF$=a$.

The resultant R may be resolved into two forces R cos. a and R sin: a of which the first tends to cause sliding along the plane FE, and is met by the resistance to shearing of the material of which the dam is composed, and by the friction of its particles upon one another. This force is not at present in question.

The latter force R sin a is the total pressure per unit of length on the base EF, and has to be met by the resistance of the material to crushing.

If the pressure were evenly distributed over the whole base EF, or if the point K correspond with the centre of EF, the pressure per unit of surface would be $\frac{\text{R Sin } a}{l}$; but if EK be not equal to one half EF, according to the generally recognised principle in such cases, the maximum pressure upon the material per unit of surface is—

$$\frac{\text{R Sin } a}{l} \times \left(1 + 6\frac{\frac{l}{2} - u}{l}\right)$$

$$= \frac{\text{R Sin } a}{l} \cdot \frac{4l - 6u}{l} \text{ or } \frac{\text{R Sin } a}{l}\left(4 - \frac{6u}{l}\right),$$

and this maximum is at E or F according as EH is less or greater than HF.

Practically in the case of a full reservoir it will always be at E.

The method adopted until recently for finding the strain upon the material at any point E in the rear face of a dam has been to take the line EF horizontal as in fig. 2, and then to assume the maximum pressure.

$\frac{\text{R Sin } a}{l} \cdot \left(4 - \frac{6u}{l}\right)$ found as above, as that which the material had to resist.

It has however been recently maintained by Mr. Bouvier, a French Engineer, that the true method of ascertaining the pressure on the material is to consider the force R as acting not upon the base EF, but upon the side FL or EM of the parallelogram EMFL, of which EF is a diagonal and the sides are respectively parallel and at right angles to the direction GH of the force R.

This of course means that the total pressure on the base is not R sin a but R, and the length of the base over which it is distributed is not l but l sin a, so that the maximum pressure, instead of being

$$\frac{\text{R Sin } a}{l}\left(4 - \frac{6u}{l}\right)$$

$$\text{is } \frac{\text{R}}{l \text{ Sin } a}\left(4 - \frac{6u}{l}\right);$$

in other words it is greater than that found by the old method, in the proportion of 1 to Sin^2a.

This method appears to have been accepted by the French engineers, but its accuracy is open to grave doubt.

As a matter of fact the force R does not act upon any such line as FL or EM, but upon EF, and the pressure upon that base due to R is and can be nothing but R sin a; there is no reason for transferring the effect of R from the actual base EF to any imaginary line such as FL or EM.

So far as the pressure on the material at E due to the portion ABEF of the dam is concerned, the old method appears perfectly sound, and if EF were the bottom of the section, the pressure thus found would represent the actual crushing strain upon the material at E.

Where this method fails is that for points above the actual foot of the rear slope, it takes no account of lines below the horizontals through those points.

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The old method gives correctly enough the pressure at E due to the portion of the dam ABEF (fig. 2), but it does not follow that a greater pressure may not be produced at this same point by the forces acting on some other portion such as ABEF, and trial shows that such greater pressure is actually produced.

It is found by trial that the actual pressure at E increases with the increase of the angle FFE′ up to a point which varies to some extent with the form of the front slope below EF, but which does not vary greatly from $FF = \frac{FF^2}{h}\ h$, being the depth of water above EF, after which it diminishes.

It is found that the actual maximum pressures as calculated by this method differ very little from those found by Mr. Bouvier's method, above mentioned and so long as the position of F′ which gives the maximum pressure for any point E in the rear slope is above the foot of the front slope, it matters very little, except for the principle involved, which method be employed.

But where F′ reaches the foot of the front slope before the pressure at E begins to diminish, which, roughly speaking, is in the lower two-sevenths of any given dam, there is a considerable difference in the results of the two methods, and this difference increases as we reach the bottom of the section. It will be seen at a glance that neither the "old" method nor Mr. Bouvier's take any account of the portion of the dam below the line EF, and that the pressure at E is the same whether the total height be AF or whether it be infinite.

By the method here advocated, the total height is an element of importance, and if the depth FD be less than $\frac{EF^2}{h}$, the maximum pressure which would occur in a dam of infinite height can never be reached, and the greatest pressure at E can be only that due to the portion of the dam ABED. It is obvious that this must be greater than that due to any lower portion ABEKD, since the additional portion gives no additional water pressure, it increases the length of the base, and tends to bring the line of the resultant nearer to the front face, that is, to increase the value of $\frac{u}{l}$.

The practical result of this is that the pressures found by the method now advocated, which in the upper $\frac{5}{7}$th of any given section of dam or somewhat, but not much, in excess of those found by Mr. Bouvier's method, and considerably greater than those on the "old" plan, in the lower $\frac{2}{7}$th gradually diminish with reference to the former and approach the latter until at the actual base of the dam the results of the old and the proposed methods coincide.

It follows also that the pressure on the rear slope of any dam at any given level is greater in the centre than on the flanks, where the level is question is the greatest depth.

The following is the process to be adopted in calculating the pressure on the rear slope of any given section by this method.

In fig: 1 let P and W be the horizontal and vertical components of the force R; let EL and AC be horizontal, FO and GM vertical and GK perpendicular to EF.

Let the area AOF$=a$, ABEN$=$A, the weight of a cubic foot of water$=p$ and of a cubic foot of masonry$=w$, let OL$=h$, LF$=d$ EN$=b$, NL$=c$, EF$=\sqrt{(b+c)^2+d^2}=l$, EH$=u$ LM $=g$, EM$=b+c-g=m$ and GM$=n$—and let g_1, g_2 and k be the perpendicular distances of the point L from the verticals passing through the centres of gravity of the areas ABEN, ENF and AFC respectively.

Let the angle FGH$=a$ FEL$=\theta$, HGM$=\phi$

Then GK$=m$ Sin $\theta+n$ Cos θ

EK$=m$ Cos $\theta=n$ Sin θ

$$u = EK - GK \tan(\phi-\theta) = \frac{m \operatorname{Cos} \Phi - n \operatorname{Sin} \phi}{\operatorname{Cos}(\phi-\theta)}$$

The total pressure upon EF is R Sin a = R Cos $(\phi-\theta)$

the maximum pressure per unit of surface at E is $\frac{R \operatorname{Cos}(\phi-\theta)}{l}\left(4-6\frac{u}{l}\right)$

$$= \frac{R \cos(\phi-\theta)}{l}\left(4-6\frac{m\cos\phi - n\sin}{l\cos(\phi-\theta)}\right)$$

$$= \frac{R}{l^2}(4l \operatorname{Cos}(\phi-\theta) - 6m \operatorname{Cos}\phi + 6n \operatorname{Sin}\phi)$$

$$\frac{R}{l^2}\{4R\,l \operatorname{Cos}\phi \operatorname{Cos}\theta + 4R\,l \operatorname{Sin}\theta - 6R\,m \operatorname{Cos}\phi + 6R\,n \operatorname{Sin}\phi\}$$

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$$= \frac{1}{l^2}(4\ (b+c)\ W + 4d\ P - 6m\ W + 6n\ P)$$

$$= \frac{W\ (4\ (b+c) - 6m) + P\ (4d + 6n)}{l^2}$$; as $m = b+c-g$, and n is $\frac{h+d}{3} - d = \frac{h-2d}{3}$ the above expression becomes.

$$\frac{W\ (6g - 2\ (b+c)\ ) + 2\ Ph.}{l^2}$$

In working out a section it is nearly always easier to find the position of the centre of gravity of the area ABEN than that of ABEF, that is to say, that the value of g^1 is simpler to find than that of g.

$$W = w\left(A + \frac{bd}{2}\right) + ap$$

and $$Wg = w\ Ag_1 + \frac{wbd}{2}g_2 + apk.$$

$$W\ (6g - 2\ (b+c)\ ) = 6w\ Ag_1 + 3wbdg_2 + 6\ apk.$$

$$-2\ (b+c)\ \left(wA + \frac{wbd}{2} + ap.\right)$$

$$= wA\ (6g_1 - 2\ (b+c)\ )$$
$$+\ wbd\ (3g_2 - (b+c)\ )$$
$$+\ ap\ (6k - 2\ (b+c)\ )$$

$g_2 = \frac{b+2c}{3}$ and $3g_2 - (b+c=c)$

So that $W\ (6g - 2\ (b+c)\ )$

$$= w\left\{A\ (6g_1 - 2\ (b+c)\ ) + + bdc\right\} + pa\left\{6k - 2\ (b+c)\right\}$$

and as $P = \frac{p}{2}(h+d)^2$ the pressure at E becomes

$$\frac{w\left\{A\ (6g_1 - 2\ (b+c)\ ) + bdc\right\} + p\left\}a\ (6k - 2\ (b+c)\ ) + h\ (h+d)^2\right\}}{l^2}$$

The following table gives the pressures on the rear slope of dams of three different sections calculated by the three different methods alluded to in this note—the maximum height being 160′.

Level below top of dam.	1st Section.			2nd Section.			3rd Section.		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Feet.	Pressures in pounds per square foot.								
80		17,581	16,856		...	...		...	...
90		17,591	17,678		...	...		...	...
100		17,354	18,378		22,100	21,504		...	...
110		17,132	18,726		21,977	22,142		...	...
120	12,000	16,881	18,178	15,000	21,794	22,013	8,000	26,519	25,600
130		16,643	16,897		21,554	20,775		26,397	24,539
140		16,406	15,263		21,299	18,965		26,219	22,619
150		16,177	13,570		21,029	16,953		25,960	20,318
160		15,967	12,000		20,785	15,000		25,699	18,000

a—Pressures as calculated by the "old" method.
b— Do. do. by Mr. Bouvier's method.
c— Do. do. by the method advocated in this note.

It will be seen that down to 130′ there is very little difference between the results of methods *b* and *c*, but that during the last 30′ the former gives larger pressures than the

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latter, in other words a dam designed to have a certain limit of pressure on the latter principle would have a slight deficiency of material if the pressures were calculated on the former.

To work out a section by direct calculation for any given limit of pressure is not a matter of serious difficulty, but it is undoubtedly very laborious, and an empirical formula which can be trusted would save a considerable amount of trouble.

Molesworth's formula $y = 7{\cdot}5\sqrt{\frac{x^3}{P}}$ is almost mathematically correct for pressures calculated on the old method and by altering the co-efficient from 7·5 to 9·0 will give fairly correct results on M. Bouvier's principle, but on the method here advocated no formula can be considered satisfactory which does not take into account the depth below the level at which the pressure is being calculated.

The following formula has been found to give results so nearly accurate that it may be adopted without risk or error.

In fig. 3: $$y = 7{\cdot}9\sqrt{\frac{x\left\{x^2+\frac{7}{4}d\,(x-d)\right\}}{p}}$$

p being the limit of pressure in *feet of water.*

or $$y = 7{\cdot}67\sqrt{\frac{x\left\{x^2+\frac{7}{4}d\,(x-d)\right\}}{p}}$$

p being in *pounds on the square foot.*

If d be greater than $\frac{x}{2}$, $\frac{x}{2}$ should be substituted for it in the formula, which then becomes $y = 1{\cdot}17\frac{\sqrt{x^3}}{p}$ or $y = 9{\cdot}25\frac{\sqrt{x^3}}{p}$ according as p in feet of water ori n pounds on the square foot.

The following table shows the values of y as worked out by direct calculation and by the formula for various heights of dam with p=18,000lb on the square foot, or 288′ of water.

Level below top of dam.	Dam 120 feet high.		Dam 130 feet high.		Dam 140 feet high.		Dam 150 feet high.		Dam 160 feet high.	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
90	57 81	57·66	58·70	58·09	58·81	58·09	58·81	58·09	58·81	58·09
100	65·00	65·08	67·18	66·97	68·46	67·97	68·88	68·8	68·88	68·28
110	70·92	70·96	74·41	74·20	76·93	76·51	78·11	78·11	79·37	79·12
120	75·52	74·76	80·41	80·10	84·20	83·65	87·04	86·48	89·01	88·47
130	,,	,,	84·96	84·96	90·59	89·69	94·36	93·66	97·49	96·98
140	,,	,,	,,	,,	95·77	94·74	100·54	99·83	104·87	104·28
150	,,	,,	,,	,,	,,	,,	105·55	105·13	111·14	110·81
162	,,	,,	,,	,,	,,	,,	,,	,,	116·28	116·12

a—Value of y as calculated by formula.

b— Do. as calculated by direct calculations.

The formula has been tested, though in less detail, for other values of p, and found equally accurate.

If great accuracy be required a trial section can be made out from the formula, and the pressures calculated in detail, the values of x at different levels can then be increased or diminished in the square root of the proportion which the desired value of p bears to the actual pressure as found by the trial section, but it will be found in most cases that the pressures in the trial section are so near the desired result that the correction is not necessary.

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No fault has been found with the old method as applied to the pressures on the front slope when the reservoir is empty; at N (fig. 1) the pressure is $\frac{Aw\,(4b-(6\,g_1-c))}{b^2}$, and if g_1-c is as for the first 120′ or so, it should be nearly $\frac{1}{3}\,b$; this becomes $\frac{2Aw}{b}$.

It is not easy to give a satisfactory formula for the value of z, based upon the limit of pressure to be allowed, as it is not till a depth of 120′ that any limit likely to be adopted in practice comes into play at all.

Molesworth's formula of $zy\,\frac{1}{10}$ =gives an unnecessary amount of material at depths of 150 and under. A vertical face for the first 40′ a slope of one in 20 for the next 40, one in 10 for the third, and so on, increasing one-twentieth at every 40′ gives satisfactory results within all practical limits. The conditions of the front face are affected by the maximum depth to which the water is allowed to fall, and in point of fact the calculation of the pressures is so much simpler than in the case of the rear face, that the section required for any given conditions can very easily be worked out, and below 120′ the effect of any variation upon the total cost of a dam is quite insignificant. The absence of an empirical formula is therefore not of much importance.

It may be as well to add a few words as to the application of the general principles herein discussed to the particular case of the Periar dam. The pressures in this dam have been calculated on the principle here advocated, and the section has been designed so that the pressure on the material shall not exceed 18,000lb on the square foot. To keep within this limit if the pressures were calculated on Mr. Bouvier's principle, the thickness of the dam would have to be increased by about 40′ of the base, by 8′ at 10′ and by 3′ at 20 feet above the base. The dimensions might be slightly reduced from 30 to 60′, and the total additional material required would be about 24,000 cubic feet, or just one-half per cent. of the quantity required by the design proposed.

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APPENDIX II.

Memorandum on the Works in the Plains of Madura.

The sections of proportions of the main channel have been laid down to various data below the floor of the head-sluice; the arrangement is an awkward one, but the datum which appertains to each sheet is shown on the sheet at the commencement of the section.

2. In cuttings through rock with heavy falls a co-efficient of 1·28 ($v=1{\cdot}28\sqrt{fs.}$) has been used, were the sides correctly trimmed a higher co-efficient might be used, but it is apprehended that the cutting through the rock will be tolerably roughly executed.

3. But slight modifications have been made in the estimate for the main channel, and those only where the channel in the 6th and 7th reaches passes through tanks and where the surface fell would not be maintained as seems to have been supposed, the necessary alterations have been made in the estimate.

4. *No. 1 Reach.*—The original designs of the proposed head and under-sluices have been passed, trifling alterations being made in the method of connecting the surplus of scoring sluices with the wing wall of the Paranay anicut, so as to afford protection to the bank connecting them. The alterations here, as elsewhere, are shown in red on the original plans, and provision for them has been made in the estimate.

Plans 33 and 34.

5. The head-sluice is larger than is required to pass the quantity of water necessary for the actual cultivation under the Vadacunay channel, the area dependent upon which is only 4,000 acres, because it is deemed desirable to interfere as little as possible with existing rights, and hence capacity is allowed in the head-sluice to admit of the passage of a supply to the Vadacunay channel equivalent to the supply the channel now receives through its open mouth under all states and conditions of the floods in the river.

6. *Plan 35, 1st Mile.*—For the same reason a large area is provided in the regulating work where the Vadacunay branches from the main channel. This regulator is to be built on rock, and the floors and aprons are to be paved with cyclopean stones (2′ deep in mortar), the foundations of the piers, wings, etc., being carried down 2′ into the rock, and the retaining walls 3′; it would be well to give the former a footing into the rock below the cyclopean flooring stones, and hence 6″ have been added to the foundations.

7. For this work baulk shutters are provided, as the cost of the work would be considerably increased were the height of the work raised so as to afford a convenient platform from which to work the solid shutters which are being generally introduced elsewhere. This regulator is completely protected from floods in the river. and the water which reaches it will be regulated by the sluice at the head of the channel, and hence there is no objection to the vents being closed by baulk shutters.

8. The head-sluice and regulating work for the main canal and Vedacunay channel are only 1,460′ apart; it is necessary, however, that both should be built, for the ground between the two works is unfavourable for an open channel. The existing channel hugs the river bank, and has frequently breached into the river.

9. At 1,940′ below the regulator two alternative lines are shown; the northern line would pass through a rocky ridge at Velamputty, for a distance of about 8,450′, with an average cutting of 14′, and would be Rl1,500 more costly than the southern line, which is only 739′ longer than the northern. Mr. Smith recommends the latter, and it is proposed to adopt it.

Sheet No. 3.

10. *Plan 45, 2nd Mile.*—Below the drop and bridge on this line sloping apron is provided. I prefer a direct overfall when the drop is so small as 5′; the tendency of the sloping apron is to scour a hole below the bed of the channel below the work; the bed is to be protected by a rough-stone apron for a length of 25′; this apron I would place at least 1 foot below the deep bed of the channel, not only here but for all the drops.

11. *No. 53, 3rd Mile.*—The piers are somewhat slight as designed, 6″ have been added to them, and the spans have been made 21 instead of 20′, so that the velocity of the stream passing under the aqueduct may not exceed the velocity in the channel.

12. *Nos. 54 and 55.*—Those works provide for the discharge of the drainage areas of the Ramarajapuram and Nachicolum tanks through which the channel is to run; the drainage basins are 75 and 14 square miles respectively, and Mr. Smith provides for the discharge of 5,330 and 2,129 cubic feet respectively, and this with a head of 9′ for the Ramarajapuram

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sluice and of 6' for the Nachicolum sluice, he appears to have considered that the tanks would absorb a portion of the water in their waterspreads, for elsewhere he provides for the discharge of 12″ in the 24 hours and here for only about 3″ in 24 hours; but with the channel running full, as the tanks are also full, the capacity of the tanks above the channel H. W. level must not be considered; and hence works 54 and 55 have been recast with capacity sufficient to discharge the drainage from the basins of the tanks, calculated from the formula D= 75,000 (M) $\frac{2}{3}$, with water in the channel as its normal full level while an ample margin is provided for its safety. The bodies of these works are *fac-similes* of the Venaur regulating works but they are provided with a drop below to prevent the enormous velocity allowed by Mr. Smith, and which would probably have torn his works to pieces; broad solid aprons are provided below the drops, and these are further protected by rough-stone aprons.

13. No. 49 provided for the passage under the channel by means of an iron pipe of the supply for the Iyengar tank, the limit of the waterspread of which the channel traverses. By some error Mr. Smith proposed to divert this channel to the rocky cutting immediately above the second branch channel; this, however, is some half a mile below the tank. The quantity of water to be passed is 450 cubic feet per second; for this three pipes, instead of one as provided, would be required, and to carry these under the channel where it is 71 feet at bottom would be very costly, namely, ₹26,400; moreover, the channel is here some 4 feet in cutting, and the higher channel would have to be carried under the lower, the most convenient arrangement for the passage of the supply for the Iyengar tank is by an inlet and outlet, and these are provided for in estimates 61* and 62† which are similar to the general plans of inlets and outlets Nos. 57 and 58, and are adapted to the positions in which they are to be placed and to pass the quantities of water required.

* ₹3,000.
† ₹4,160.

14. Mr. Smith has provided for the discharge by the inlets and outlets of half an inch of drainage over the whole area of the basins, the discharge from which has to be passed across the main channel when the area drained exceeds 5 square miles. Provision for so large a discharge is unnecessary, and in revising the work provision has been made for the discharge of the quantities of water calculated from the formula D=75,000 (M) $\frac{2}{3}$, and this discharge has been provided for by the inlets, with the water level in the channel 6″ above the H. W. level to be maintained, while discharge by the outlets has been provided for with the water at H. W. level in the channel, and as the channel banks are 6′ above H. W. level, and ample margin for safety has thus been allowed.

15. As explained by Mr. Smith, the main channel is to be carried under the Shattiyaur‡ and Morangalier streams which discharge the drainage of 25 and 56 square miles respectively, as for the inlets and outlets, so for these streams Mr. Smith has provided for the discharge of $\frac{1}{2}$″ per hour of rainfall over the whole area drained. It is sufficient to provide for the discharge of 7″·15 in the former case and 5″·5 in the latter, and the works have been altered accordingly; for the latter work, however, the discharge is provided for with a depth of 6′ over the aqueduct, instead of 7′ as proposed by Mr. Smith, and an ample margin for safety is allowed in providing wings 3′ above the anticipated maximum flood level; the pipes to be covered by a layer of concrete 1 foot thick, as the fall in the stream is very heavy (20 feet per mile) and the velocity over the work will be nearly 14·5′ per second.

‡ No. 65 in 20th mile.
No. 66 in 20th mile.

16. *No. 60.*—For the passage of the main channel under the Morangalier, Mr. Smith provides five pipes, 6′ in diameter, with a fall 2′ 0$\frac{3}{4}$″ through the pipes; this with a co-efficient of $\frac{5}{8}$ths would hardly provide sufficient waterway (calculating the discharge as through a sluice as the pipe is a short one), and as it is well in such cases to provide a margin, a sixth pipe has been added.

17. The bridge in the 26th mile, No. 73, has been modified; in the original design the arch springs from rock 3′ above the channel bed, and, as the water is 6′ deep, a portion of the arch would always have been submerged; as the velocity through the rocks cutting will be upwards of 10′ feet per second, the work has been revised, so that the arch may spring from rock, but above the maximum water level in the channel.

18. Works 46 to 49 provide for weirs or drops where the level in the water has to be lowered in the 11th reach; these works are according to the models used in the Northern Deltas, and are provided with long sloping roughstone aprons which, if injured, are easily restored by throwing in more stone; the form of apron cannot but tend to induce action on the channel bed below the weirs, but where stone is abundant the form adopted for the weirs is probably cheaper than the form adopted in the Southern Delta, but the up-keep is probably more expensive for the former than for the latter until the bed of the channel really consists of roughstone to a point beyond which the action from the weir ceases to be sufficient to move the soil of which the bed of the

33rd to 35th mile.

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channel consists. Though I would advocate the adoption of the weir with a clear fall, I have not deemed it necessary to alter the weirs proposed, which belong to a school in which I have not served an apprenticeship, and with the practical working of which I am not personally acquainted.

19. The only alteration made in these works is to carry the lower retaining walls down to 7½ instead of 5′ below the channel beds, for the safety of the works in a very great measure depends upon the stability of these retaining walls.

20. The other masonry works in the main channel do not appear to require special comment, they are simple in their nature, are suitable for the positions in which they are to be placed, and provide sufficient waterway for the quantities they may be called upon to discharge.

21. The main branches from the channel are to traverse the crests of ridges, thus commanding both sides of the spurs they traverse, and hence the maximum area, and obviating the necessity of providing passages for drainage as would be necessary were the channels carried at a lower level in an undulating country. In following the ridges a heavy fall has to be overcome, and this has been done by providing drops where necessary, and by giving the channels heavy fall, and allowing them to carry only 2′ of water, thus maintaining a comparatively low velocity.

22. Where depressions in the ridges which the branch channels traverse have to be crossed, the channels are banked on both sides and are puddled; these hollows would soon become silted up.

23. The petty works for the branch channels appear to provide amply for the duty they have to perform. The weirs or drops provided in the original estimate were of the nature described in paragraph 18; but as some of the weirs are as small as only 3′ in length, and as the depth of water in these channels is only to be 2′, it has been deemed advisable in weirs up to 16′ in length discharging up to 160 cubic feet per second to adopt the form of weirs used in the Southern Delta providing a clear overfall; a saving of ₹80,826 on Mr. Smith's estimate has thereby been effected, and the estimate for the branch channels now amounts to ₹6,87,060 against ₹7,88,220 as originally prepared.

24. The capacity of all the weirs is one-fifth in excess of that required for the land dependent upon them, as the quantity of land now irrigated under the tanks (it is proposed to do away with) may not in every case bear the same proportion to the new lands to be supplied by each branch channel; until the whole land to be supplied by each branch channel is brought under cultivation, a portion of the weirs may be walled up to prevent a draught and an increase of velocity as the water approaches the weirs.

25. In the estimates for all the masonry works, sundries at the rate of 5 per cent. have been provided. Mr. Smith, as a rule, provided only 2½ per cent., and hence the amounts of many of the estimates have been altered in which no change in details or design has been made.

26. The rock through which both the tunnel through the ridge and the temporary escape tunnel are to be pierced, is stated to consist of sienite; it would be well that these spots should be examined by a member of the Geological Survey Department, with a view to his reporting on the probability or otherwise of the rock being solid throughout, or of fissures being met with, and the advisability or otherwise of working from one and only, or from the several shafts it is proposed to carry down to the tunnel, for, with a fall of 77′ in a mile, workmen would soon be driven from an upper or obstructed cutting if water in any quantity appeared.

18th January 1863. R. F. OAKES, *Major, R.E.*

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Particulars of Estimated Debits to Capital (excluding interest) up to date of Completion of Works and opening of Revenue Accoun

Form No. 1 of Circular from Government of India, No. XVII P.W. of 1880.

Year.	Direct charges.				Indirect charges other than interest.				Grand Total without interest.	Remarks.
	Works.	Establishment.	Tools and Plant.	Total.	Capitalised abatment of land r venue.	Loss by exchange on payments in England.	Charges for leave and pension allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11
First	4,00,000	50,000	5,000	4,55,000	17,000	...	12,500	12,500	4,67,500	Estimated progress of works.
Second	8,00,000	1,75,000	11,000	9,86,000	17,000	...	43,750	60,750	10,46,750	First year, construction of road, preparation of site, purchase and erection of machinery.
Third	8,00,000	1,75,000	11,000	9,86,000	17,000	...	43,750	60,750	10,46,750	
Fourth	8,00,000	1,75,000	11,000	9,86,000	17,000	...	43,750	60,750	10,46,750	Second to Sixth } uniform progress.
Fifth	8,00,000	1,75,000	11 000	9,86,000	17,000	...	43,750	60,750	10,46,750	
Sixth	8,00,000	1,75,000	11,000	9,86,000	17,413	...	43,750	61,163	10,47,163	Seventh and eighth, payment to Travancore Government.
Seventh	4,00,000	...	...	4,00,000	...	...	...	...	4,00,000	
Eighth	4,00,000*	...	...	4,00,000	...	...	...	...	4,00,000	
Total	52,00,000	9,25,000	60,000	61,85,000	85 413	...	2,31,250	3,16,663	65,01,663	

* Works 42,16,180 Establishment at 22 per cent., and tools and plant at 1¼ per cent. on works, outlay, less R 2.50,000 for—
Land 9,83,820 machinery obtained from England.

52,00,000

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Summary of the Net Estimated Direct Charges to Capital Account and Simple Interest up to date of completion of works and opening of Revenue Account.

Form No. 2 of Circular from Government of India No. XVII P. W. of 1880.

Year.	Debits to Capital.	Sum on which interest is calculated.			Simple Interest at 4 per cent. on Column 5.	Remarks.
		Debits to end of previous year.	Half debits during year.	Total Columns 3 and 4.		
	R	R	R	R	R	
First	4,55,000	...	2,27,500	2,27,500	9,100	
Second	9,86,000	4,55,000	4,93,000	9,48,000	37,920	
Third	9,86,000	14,41,000	4,93,000	19,34,000	77,360	
Fourth	9,86,000	24,27,000	4,93,000	29,20,000	1,16,800	
Fifth	9,86,000	34,13,000	4,93,000	39,06,000	1,56,240	
Sixth	9,86,000	43,99,000	4,93,000	48,92,000	1,95,680	
Seventh	4,00,000	53,85,000	2,00,000	55,85,000	1,73,448 (*a*)	(*a*) After deduction of R49,960 being net revenue in this year.
Eighth	4,00,000	57,85,000	2,00,000	59,85,000	1,39,480 (*b*)	(*b*) After deduction of R99,920 being net revenue in this year.
Total	61,85,000				9,06,020	

* Together R70,91,020, with indirect charges R 74,07,683, on which R5,74,600 the net earnings due to the works (*vide* Form 3) is 7·76 per cent.

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Estimate of Growth Irrigation and Revenue Receipts and Charges.

Form No. 3 of Circular from Government of India No. XVII P. W. of 1880.

Year.	Area irrigated by project at end of year.	REVENUE RECEIPTS AND CHARGES.									
		Revenue due to Works.					Charges against Revenue Accounts.			Net earnings due to works.	
		Direct Receipts.			Share of enhanced Land Revenue or Indirect Receipts.	Total Columns 5 and 6.	Maintenance Charges, Public Works Department (at 8 annas per acre irrigated).	Collection Charges, Revenue Department, at 7·2 per cent. on Revenue.	Total.	Including enhanced Land Revenue.	Excluding enhanced Land Revenue.
		Public Works Department.	Revenue Department.	Total.							
1	2	3	4	5	6	7	8	9	10	11	12
	Acres.	R	R	R	R	R	R	R	R	R	R
Seventh	14,000	...	70,000	70,000	...	70,000	15,000	5,040	20,040	49,960	49,960
Eighth	28,000	...	1,40,000	1,40,000	...	1,40,000	30,000	10,080	40,080	99,920	99,920
Ninth	42,000	...	2,10,000	2,10,000	...	2,10,000	45,000	15,120	60,120	1,49,880	1,49,880
Tenth	56,000	...	2,80,000	2,80,000	...	2,80,000	60,000	20,160	80,160	1,99,840	1,99,840
Eleventh	70,000	...	3,50,000	3,50,000	...	3,50,000	75,000	25,200	100,200	2,49,800	2,49,800
Twelfth	84,000	...	4,20,000	4,20,000	...	4,20,000	75,000	30,240	105,240	3,14,760	3,14,760
Thirteenth	98,000	...	4,90,000	4,90,000	...	4,90,000	75,000	35,280	110,280	3,79,720	3,79,720
Fourteenth	1,12,000	...	5,60,000	5,60,000	...	5,60,000	75,000	40,320	115,320	4,44,680	4,44,680
Fifteenth	1,26,000	...	6,30,000	6,30,000	...	6,30,000	75,000	45,360	120,360	5,09,640	5,09,640
Sixteenth	1,40,000	...	7,00,000	7,00,000	...	7,00,000	75,000	50,400	125,400	5,74,600	5,74,600

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Sub-head.	Names of Works.	Amount of Estimate for Individual Works.	Total of Sub-heads.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		R	R	R	R
	Classified Abstract Estimate of the Periar Project in the Madura District.				
	DIRECT CHARGES.				
	I.—Works.				
	(1.) Head Works.				
	Works in the Periar Valley.				
A. Preliminary Expenses	Share of expenditure already incurred	52,000			
	Probable further expenditure . .	28,000	80,000		
B. Land . . .	Compensation of Travancore Government for site of works . . .	8,00,000	8,00,000		
C. Works . . .	Main dam	9,20,000			
	Temporary dams	15,000			
	Escape culvert	25,000			
	Turbine supply culvert . . .	14,000			
	Right bank escape	1,55,000			
	Left bank escape	46,000			
	Watershed cutting	1,37,000			
	Watershed tunnel	2,95,000	16,07,000		
K Building . .	Buildings and lines as per detailed abstract No. 9	1,57,000	1,57,000		
O. Miscellaneous .	Road from watershed to site of works, and footpaths in and about works .	56,000	56,000		
P. Maintenance . .	Maintenance of works during construction	50,000	50,000		
	Total of works in the Periar Valley .		...	27,50,000	
	Works in the Valley of the Soorollyar.				
A. Preliminary Expenses	Share of expenditure already incurred	5,000	5,000		
C. Works . . .	Regulating sluices Ootamuth Weir .	20,000			
	Paliamparva	25,400			
	Ootampolliam	20,000			
	Makincotta	25,400			
	Coochinoor	25,400			
	Seliamputty	19,620			
	Kotahur	17,710			
	Gulianur	25,400			
	Oopperaputty	25,400			
	Veerapandy	17,710			
	Chuttraputty	17,710			
	Pulinchetty	25,400			
	Fall of 8'2" adjacent to the Paliamparava regulating sluice . .	20,470	3,11,020		
P. Maintenance . .	Maintenance of works during construction	13,980	13,980		
	Total works in the Sooroolly Valley .			3,30,000	
	Total (1) Head Works . . .				30,80,000
	(2.) *Main Canals and Branches.*				
A. Preliminary Expenses	Share of expenditure already incurred	15,000			
	Probable further expenditure . .	3,000	18,000		
				18,000	

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Sub-head.	Names of Works.	Amount of Estimate for Individual Works.	Total of Sub-heads.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		₹	₹	₹	₹
	Main Channel, 1st Reach.				
B. Land	73 Acres wet land	31,050			
	18 „ dry „	3,495	34,545		
D. Regulators	Repairs to Peranny anicut	5,000			
	Head sluice	71,700			
	Regulator	20,800	97,500		
E. Falls and Weirs	Fall Plan No. 45	6,200	6,200		
F. Cross Drainage Works	5 Culverts, Plan No. 52	32,500			
	2 Acqueducts, Plan No. 53	7,800			
	Surplus sluice, Plan No. 52	34,000			
	Surplus sluice, Plan No. 55	16,100	90,400		
G. Bridges	Bridge, Plan No. 69	5,700			
	Bridge for South Indian Railway	10,000	15,700		
L. Earthwork	Earthwork as per separate detailed abstract	1,40,655	1,40,655		
	Total Main Channel, 1st Reach			3,85,000	
	Main Channel, 2nd Reach.				
B. Land	5 Acres wet land	1,750			
	92 „ dry „	3,960	5,710		
F. Cross Drainage Works	Culvert, Plan No. 52	6,500			
	Inlet, Plan No. 57	4,100			
	Outlet, Plan No. 58	8,280			
	Inlet, Plan No. 59	4,570			
	Outlet, Plan No. 60	10,680			
	Inlet, Plan No. 62	4,160			
	Outlet, Plan No. 61	3,000	41,290		
G. Bridges	Bridge, Plan No. 69	5,700			
	Repairing trunk road and altering masonry works	4,250			
	Diversion of trunk road	2,370	12,320		
L. Earthwork	Earthwork as per separate detailed abstract	34,680	34,680		
	Total Main Channel, 2nd Reach			94,000	
	Main Channel, 3rd Reach.				
B. Land	14 Acres wet land	5,800			
	243 „ dry „	10,945	16,715		
D. Regulators	3 Irrigation sluices	5,310	5,310		
F. Cross Drainage Works	6 Inlets, Plan No. 56	24,600			
	6 Outlets „ „ 58	49,680			
	Inlet „ „ 63	6,200			
	Outlet „ „ 64	17,300	97,780		
G. Bridges	3 Bridges, Plan No. 70	10,500	10,500		
L. Earthwork	Earthwork as per separate detailed abstract	71,665	71,665		
	Total Main Channel, 3rd Reach			2,02,000	
	Main Channel, 4th Reach.				
B. Land	23 Acres wet land	8,350			
	3 „ dry „	105	8,455		

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Sub-head.	Names of Works.	Amount of Estimate for Individual Work.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		₹	₹	₹	₹
D. Regulators . .	Irrigation sluice, Plan No. 37 . .	1,770	1,770		
F. Cross Drainage Works	Inlet, Plan No. 57	4,100			
	Outlet „ „ 58 . . .	8,280	12,380		
L. Earthwork . .	Earthwork as per separate detailed abstract	8,395	8,395		
	Total Main Channel, 4th Reach .			31,000	
	Main Channel, 5th Reach.				
B. Land . . .	19 Acres wet land . . .	8,550			
	51 „ dry „ . . .	2,425	10,557		
F. Cross Drainage Works	Culvert and aqueduct combined in lieu of Shattryaur, Plan No. 65 . .	22,650			
	Do. of Marangaliar Plan No. 66	64,000			
	Inverted syphon, Plan No. 72 . .	6,690	93,340		
G. Bridges . .	Bridge, Plan No. 71 . . .	3,640			
	„ „ „ 72 . . .	4,010	7,650		
L. Earthwork . .	Earthwork as per separate detailed abstract	29,035	29,035		
	Total Main Channel . . .			1,41,000	
	Main Channel, 6th Reach.				
B. Land . . .	14 Acres wet land	9,900			
	55 „ dry „	2,305	12,205		
F. Cross Drainage Works	2 Inverted syphons, Plan No. 67 .	12,300			
	Inlet, Plan No. 57	4,100			
	2 Outlets, Plan No. 58 . . .	16,560	32,960		
G. Bridges . .	Bridge, Plan No. 72 . . .	3,460	3,460		
L. Earthwork . .	Earthwork as per separate detailed abstract	35,375	35,375		
	Total Main Channel, 6th Reach .			84,000	
	Main Channel, 7th Reach.				
B. Land . . .	11 Acres wet land	3,850			
	39 „ dry „	1,465	5,315		
F. Cross Drainage Works	3 Inlets, Plan No. 57 . . .	12,300			
	3 Outlets, „ „ 58 . . .	24,840	37,140		
G. Bridges . .	Bridge, Plan No. 73 . . .	1,040			
	Diversion of road . . .	1,100	2,140		
L. Earthwork . .	Earthwork as per separate detailed abstract	22,405	22,405		
	Total Main Channel, 7th Reach .			67,000	
	Main Channel, 8th Reach.				
B. Land . . .	18 Acres wet land	6,600			
	25 „ dry „	875	7,475		
F. Cross Drainage Works	Inlet, Plan No. 57	4,100			
	Outlet, „ 58	8,280	12,380		

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Sub-head.	Names of Works.	Amount of Estimate for Individual Work.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		₹	₹	₹	₹
G. Bridges . .	Bridge, Plan No. 74 . . .	...	...		
L. Earthwork . .	Earthwork as per separate detailed abstract	9,475	9,475		
	Total Main Channel, 8th Reach .			33,000	
	Main Channel, 9th Reach.				
B. Land . . .	27 Acres dry land	810	810		
D. Regulators . .	Irrigation sluice, Plan No. 37 . .	1,770	1,770		
F. Cross Drainage Works	2 Inlets, Plan No. 57 . . .	8,200			
	2 Outlets, ...	16,660	24,760		
L. Earthwork . .	Earthwork as per separate detailed abstract	5,660	5,660		
	Total Main Channel, 9th Reach .			33,000	
	Main Channel, 10th Reach.				
B. Land . . .	27 Acres dry land	810	810		
D. Regulators . .	Irrigation sluice, Plan No. 37 . .	1,770	1,770		
F. Cross Drainage . .	2 Inlets, Plan No. 57 . . .	8,200			
	2 Outlets, „ 58 . . .	16,560	24,760		
L. Earthwork . .	Earthwork as per separate detailed abstract	3,660	3,660		
	Total Main Channel, 10th Reach .			31,000	
	Main Channel, 11th Reach.				
B. Land . . .	32 Acres wet land	6,600			
	43 „ dry „	1,290	7,890		
D. Regulators . .	Irrigation sluice, Plan No. 37 . .	1,770	1,770		
E. Falls and Weirs .	2 Falls, Plan No. 46 . . .	6,200			
	2 „ No. 47 . . .	5,480			
	Fall, Plan No. 48	3,680			
	„ „ No. 49	630	15,990		
F. Cross Drainage Works	4 Inlets, Plan No. 57 . . .	16,800			
	9 Outlets, Plan No. 58 . . .	74,520	91,320		
G. Bridges . .	Bridge, Plan No. 75 . . .	2,380	2,380		
L. Earthwork . .	Earthwork as per separate detailed abstract	30,650	30,650		
	Total Main Channel, 11th Reach .			1,50,000	
	Main Channel, 12th Reach.				
B. Land . . .	9 Acres wet land	27,000			
	18 „ dry „	900	3,600		
F. Cross Drainage Works	2 Inlets, Plan No. 57 . . .	8,200			
	2 Outlets, „ No. 58 . . .	16,560	24,760		
G. Bridge . . .	Bridge, Plan No. 75 . . .	2,380	2,380		

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Sub-head.	Names of Works.	Amount of Estimate for Individual Work.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		R	R	R	R
L. Earthwork . .	Earthwork as per separate detailed abstract	4,260	4,260		
	Total Main Channel, 12th Reach .			35,000	
	Buildings.				
K. Buildings . .	Rent or purchase of buildings for use in connection with the main channel .	10,000	10,000	10,000	
	Maintenance.				
P. Maintenance .	Maintenance of works during construction	53,000	53,000	53,000	
	Total (2) Main Canals and Branches .				1,36,700
	(3.) Distributaries.				
A. Preliminary Expenses	Share of expenditure already incurred .	7,665			
	Probable further expenditure . .	2,335	10,000	10,000	
	First Branch Channel.				
B. Land . . .	45 acres wet land	16,250	16,250		
D. Regulators . .	Head sluice, Plan No. 37 . .	1,770	1,770		
E. Falls and Weirs .	5 Falls, Plan No. 51 . . .	3,600			
	3 „ „ No. 51 . . .	2,220	5,820		
F. Cross Drainage Works	2 Culverts, Plan No. 68 . .	5,480	5,480		
L. Earthwork . .	Earthwork as per separate detail abstract	13,530	13,530		
O. Miscellaneous .	2 Irrigation sluices, Plan No. 41 .	660			
	3 Do. do. , Plan No. 42 .	960			
	3 Do. do. , Plan No. 43 .	930			
	2 Do. do. , Plan No. 44 .	600	3,150		
	Total First Branch Channel . .			46,000	
	Second Branch Channel.				
B. Land . . .	18 Acres dry land . . .	810	810		
D. Regulators . .	Head sluice, Plan No. 37 . .	1,770	1,770		
E. Falls and Weirs .	1 fall, Plan No. 51 . . .	670			
	2 falls, „ No. 51 . . .	1,280	1,950		
F. Cross Drainage Works	Culvert, Plan No. 68 . . .	2,740	2,740		
G. Bridges . .	Road tunnel, Plan No. 77 . .	960	960		
L. Earthwork . .	Earthwork as per separate detail abstract	5,500	5,500		
O. Miscellaneous .	3 Irrigation sluices, Plan No. 42 .	960			
	1 Do. sluice, Plan No. 42 .	310	1,270		
	Total Second Branch Channel . .			15,000	
	Third Branch Channel.				
	70 acres dry land . . .	3,150	3,150		

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Sub-head.	Names of Works.	Amount of Estimate for Individual Work.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		R	*R*	*R*	*R*
D. Regulators . .	2 Head sluices, Plan No. 37 . .	3,540			
	Regulator, Plan No. 39 . . .	480	4,020		
E. Falls and Weirs .	3 Falls, Plan No. 51 . . .	2,310			
	2 Do. „ „ „ . . .	1,520			
	2 Do. „ „ „ . . .	1,440			
	2 Do. „ „ „ . . .	1,420			
	3 Do. „ „ „ . . .	2,010	8,700		
F. Cross Drainage Works	Culvert, Plan No. 68 . . .	2,740	2,740		
L. Earthwork . .	Earthwork as per separate detailed abstract	9,240	9,240		
O. Miscellaneous .	5 Irrigation sluices, Plan No. 41 .	1,650			
	4 „ „ „ „ 42 .	1,280			
	2 „ „ „ „ 43 .	620			
	2 „ „ „ „ 44 .	600	4,150		
	Total Third Branch Channel . .			32,000	
	Fourth Branch Channel.				
B. Land . . .	180 Acres dry land . . .	8,100	8,100		
D. Regulators . .	Head sluice, Plan No. 36 . .	2,500			
	„ „ „ „ 37 . . .	1,770			
	5 Regulators „ „ 39 . . .	2,400	6,670		
E. Falls and Weirs .	2 Falls, Plan No. 50 . . .	3,440			
	1 Fall „ „ 50 . . .	1,710			
	3 Falls „ „ 51 . . .	2,190			
	2 „ „ „ 51 . . .	1,400			
	2 „ „ „ 51 . . .	1,340			
	2 „ „ „ 51 . . .	1,280			
	2 „ „ „ 51 . . .	1,780			
	2 „ „ „ 51 . . .	1,740			
	2 „ „ „ 51 . . .	1,600			
	3 „ „ „ 51 . . .	2,250	18,730		
G. Bridges . .	3 Road tunnels, Plan No. 41 . .	2,370	2,370		
L. Earthwork . .	Earth-work as per separate detailed abstract	37,750	37,750		
O. Miscellaneous .	14 Irrigation sluices, Plan No. 41 .	4,620			
	6 „ „ „ „ 42 .	1,920			
	4 „ „ „ „ 43 .	1,240			
	2 „ „ „ „ 44 .	600	8,380		
	Total Fourth Branch Channel . .			82,000	
	Fifth Branch Channel.				
B. Land . . .	55 Acres dry land . . .	2,525	2,525		
D. Regulators . .	Head sluice, Plan No. 37 . . .	1,770			
	Regulator, „ „ 39 . . .	480	2,250		
E. Falls and Weirs .	5 Falls, Plan No. 51 . . .	3,500			
	3 „ „ „ „ „ . . .	2,010			
	4 „ „ „ „ „ . . .	2,560			
	2 „ „ „ „ „ . . .	1,220			
	2 „ „ „ „ „ . . .	1,180	10,470		
F. Cross Drainage Works.	2 Wrought-iron aqueducts . .	1,500	1,500		
L. Earthwork . .	Earthwork as per separate detailed abstract	10,665	10,665		
O. Miscellaneous .	4 Irrigation sluices, Plan No. 41 .	1,320			

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Sub-head.	Names of Works.	Amount of Estimate for Individual Works.	Total of Sub-heads.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		R	R	R	R
	3 Irrigation sluices, Plan No. 42 .	960			
	1 „ „ „ „ 43 .	310	2,590		
	Total Fifth Branch Channel . .			30,000	
	Sixth Branch Channel.				
B. Land . . .	15 Acres dry land . . .	525	525		
D. Regulators . .	Head sluice, Plan No. 37 . .	1,770	1,770		
E. Falls and Weirs .	3 Falls, Plan No. 51 . . .	1,980			
	1 Fall „ „ 51 . . .	650			
	2 Falls „ „ 51 . . .	1,280			
	1 Fall „ „ 51 . . .	630			
	2 Falls „ „ 51 . . .	1,200	5,740		
G. Bridges . .	Road tunnel, Plan No. 79 . .	790	790		
L. Earthwork . .	Earthwork as per separate detailed abstract	6,745	6,745		
O. Miscellaneous .	2 Irrigation sluices, Plan No. 41 .	660			
	3 „ „ „ „ 42 .	960			
	1 „ sluice, „ „ 43 .	310	1,930		
	Total Sixth Branch Channel . .			17,500	
	Seventh Branch Channel.				
B. Land . . .	20 Acres dry land . . .	1,000	1,000		
D. Regulators . .	Head sluice, Plan No. 37 . . .	1,770	1,7 0		
E. Falls and Weirs .	5 Falls, Plan No. 51 . . .	2,850			
	3 „ „ „ „ . . .	1,740	4,590		
L. Earthwork . .	Earthwork as per separate detailed abstract	1,460	1,460		
O. Miscellaneous .	2 Irrigation sluices, Plan No. 41 .	660			
	2 „ „ „ „ 43 .	620	1,280		
	Total Seventh Branch Channel . .			10,100	
	Eighth Branch Channel.				
B. Land . . .	60 Acres dry land	2,900	2,900		
D. Regulators . .	Head sluice, Plan No. 37 . . .	1,770			
	2 Regulators „ „ 39 . . .	960	2,730		
E. Falls and Weirs .	5 Falls, Plan No. 51 . . .	3,400			
	4 „ „ „ „ . . .	2,520			
	3 „ „ „ „ . . .	1,830	7,750		
L. Earthwork . .	Earthwork as per separate detailed abstract	7,090	7,090		
O. Miscellaneous .	3 Irrigation sluices, Plan No. 41 .	990			
	1 „ sluice, Plan No. 42 .	320			
	2 „ sluices, Plan No. 43 .	620	1,930		
	Total Eighth Branch Channel . .			22,400	
	Ninth Branch Channel.				
B. Land . . .	290 Acres dry land . . .	12,950	12,950		
D. Regulators . .	Head sluice, Plan No. 36 . .	2,500			

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Sub-head.	Names of Works.	Amount of Estimate for Individual Works.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main-head.
1	2	3	4	5	6
		₹	₹	₹	₹
D. Regulators . .	Head sluice, Plan No. 37 . . .	1,700			
	5 Regulators, Plan No. 39 . .	2,400	6,670		
E. Falls and Weirs .	5 Falls, Plan No. 50 . . .	10,350			
	4 „ „ „ . . .	4,120			
	4 „ „ 51 . . .	3,440			
	1 Fall „ „ . . .	700			
	5 Falls „ „ . . .	3,750			
	2 „ „ „ . . .	1,440			
	2 „ „ „ . . .	1,400			
	3 „ „ „ . . .	2,040			
	8 „ „ „ . . .	5,360			
	1 Fall „ „ . . .	650			
	4 Falls „ „ . . .	2,560			
	5 Do „ „ . . .	3,050	38,930		
F. Cross Drainage Works	6 Culverts, Plan No. 68 . . .	16,440	16,440		
G. Bridges . .	2 Road tunnels, Plan No. 76 . .	2,540			
	1 Road tunnel, „ 77 . .	960	3,500		
L. Earthwork . .	Earthwork as per separate detailed abstract	56,640	56,640		
O. Miscellaneous .	6 Irrigation sluices Plan No. 40 .	2,640			
	18 „ „ „ 41 .	5,940			
	13 „ „ „ 42 .	4,160			
	3 „ „ „ 43 .	930			
	4 „ „ „ 44 .	1,200	14,870		
	Total Ninth Branch Channel . .			1,50,000	
	Tenth Branch Channel.				
B. Land . . .	5 Acres wet land . . .	1,750			
	295 „ dry land . . .	10,325	12,075		
D. Regulators . .	Head sluice, Plan No. 36 . . .	2,500			
	„ „ 37 . . .	1,770			
	„ „ 38 . . .	840			
	3 Regulators	1,440	6,550		
E. Falls and Weirs .	7 Falls, Plan No. 50 . . .	13,860			
	2 „ „ „ . . .	3,940			
	1 Fall „ „ . . .	1,960			
	2 Falls „ „ . . .	3,040			
	2 „ „ 51 . . .	1,740			
	2 „ „ „ . . .	1,620			
	1 Fall „ „ . . .	800			
	2 Falls „ „ . . .	1,560			
	3 „ „ „ . . .	2,280			
	4 „ „ „ . . .	3,000			
	2 „ „ „ . . .	1,260			
	2 „ „ „ . . .	1,200	36,260		
F. Cross Drainage Works . . .	19 Culverts, Plan No. 68 . .	52,060	52,060		
G. Bridges . .	Road tunnel, Plan No. 76 . .	1,270	1,270		
L. Earthwork . .	Earthwork as per separate detailed abstract	66,225	66,225		
O. Miscellaneous .	8 Irrigation sluices, Plan No. 40 .	3,520			
	9 „ „ 41 .	2,970			
	11 „ „ 42 .	3,520			
	5 „ „ 43 .	1,550	11,560		
	Total Tenth Branch Channel . .	...	...	1,86,000	

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Sub-head.	Names of Works.	Amount of Estimate for Individual Works.	Total of Sub-head.	Total for each Canal or Distributary.	Total of each main head.
1	2	3	4	5	6
		R	R	R	R
	Eleventh Branch Channel.				
B. Land . . .	70 Acres dry land . . .	3,150	3,150		
D. Regulators . .	Head sluice, Plan No. 37 . . .	1,770			
	Regulator, „ No. 39 . . .	480	2,250		
E. Falls and Weirs .	1 Fall, Plan No. 51 . . .	800			
	4 Falls „ „ . . .	3,120			
	1 Fall, „ „ . . .	760	4,680		
G. Bridges . .	Road tunnel, Plan No. 77 . .	960	960		
L. Earthwork . .	Earthwork as per separate detailed abstract	13,150	13,150		
O. Miscellaneous .	10 Irrigation sluices, Plan No. 42 .	3,200			
	1 „ sluice, „ 43 .	310			
	1 „ „ „ 44 .	300	3,810		
	Total Eleventh Branch Channel .			28,000	
	Twelfth Branch Channel.				
B. Land . . .	130 Acres dry land . . .	5,850	5,850		
D. Regulators . .	Head sluice, Plan No. 36 . .	2,500			
	3 Regulators, „ No. 30 . .	1,440	3,940		
E. Falls and Weirs .	Fall, Plan No. 50	2,040	2,040		
G. Bridges . .	1 Road tunnel, Plan No. 76 . .	1,270			
	1 „ „ „ No. 77 . .	960			
	1 „ „ „ No. 79 . .	790	3,020		
L. Earthwork . .	Earthwork as per separate detailed abstract	54,220	54,220		
O. Miscellaneous .	2 Irrigation sluices, Plan No. 40 .	880			
K. Buildings . .	16 „ „ „ No. 41 .	5,280			
	5 „ „ „ No. 42 .	1,600			
P. Maintenance .	7 „ „ „ No. 43 .	2,170	9,930		
	Total Twelfth Branch Channel . .	...	...	79,000	
	Rent or purchase of buildings for use in connection with the branch channels	5,000	5,000	5,000	
	Maintenance of works during construction	40,000	40,000	40,000	
	Total (3) distributaries . . .	...	...	...	7,53,000
	Total works	...	52,00,000		
	Establishment (Statement No. III) .	...	9,25,000		
	Tools and plant (Statement No. IV) .	...	60,000		
	Total direct charges . . .	...	...	61,85,000	
	Indirect Charges.				
	Capitalization of the abatement of revenue (Statement No. V) . .	...	85,413		
	Leave and pension allowances (25 per cent. of establishment charges) .	...	2,31,250		
	Total indirect charges . . .	...	...	3,16,663	
	Grand total without interest . .	...	...	...	65,01,633

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General Abstract Estimates of the Periar

	A. Preliminary Expenses.	B. Land.	C. Works.	D. Regulators.	E. Falls and Weirs.
(1) Head Works.					
Works in the Periar Valley . .	80,000	8,00,000	16,07,000	.....	.....
Works in the Sooroollyar Valley . .	5,000	.....	3,11,020	.....	.....
Total .	85,000	8,00,000	19,18,020	.....	.....
(2) Main Canals and Branches.					
Preliminary Expenses . . .	18,000	.....	.....	.....	.....
Main Channel, First Reach . .	.....	34,545	.....	97,500	6,200
Do. Second „ . .	.....	5,710	.....	.....	.....
Do. Third „ . .	.....	16,745	.....	5,310	.....
Do. Fourth „ . .	.....	8,455	.....	1,770	.....
Do. Fifth „ . .	.....	10,975	.....	.....	.....
Do. Sixth „ . .	.....	12,205	.....	.....	.....
Do. Seventh „ . .	.....	5,315	.....	.....	.....
Do. Eighth „ . .	.....	7,475	.....	.....	.....
Do. Ninth „ . .	.....	810	.....	1,770	.....
Do. Tenth „ . .	.....	810	.....	1,770	.....
Do. Eleventh „ . .	.....	7,890	.....	1,770	15,990
Do. Twelfth „ . .	.....	3,600	.....	.....	.....
Temporary Buildings . . .	.....	.....	.....	.....	.....
Maintenance during Construction .	.....	.....	.....	.....	.....
Total .	18,000	1,14,535	.....	1,09,890	22,190
(3) Distributaries.					
Preliminary Expenses . . .	10,000	.....	.....	.....	.....
First Branch Channel . . .	.....	16,250	.....	1,770	5,820
Second do. . . .	.....	810	.....	1,770	1,950
Third do. . . .	.....	3,150	.....	4,020	8,700
Fourth do. . . .	.....	8,100	.....	6,670	18,730
Fifth do. . . .	.....	2,525	.....	2,250	10,470
Sixth do. . . .	.....	525	.....	1,770	5,740
Seventh do. . . .	.....	1,000	.....	1,770	4,590
Eighth do. . . .	.....	2,900	.....	2,730	7,750
Ninth do. . . .	.....	12,950	.....	6,670	38,930
Tenth do. . . .	.....	12,075	.....	6,550	36,260
Eleventh do. . . .	.....	3,150	.....	2,250	4,680
Twelfth do. . . .	.....	5,850	.....	3,940	2,040
Temporary Buildings . . .	.....	.....	.....	.....	.....
Maintenance during Construction .	.....	.....	.....	.....	.....
Total .	10,000	69,285	.....	42,160	1,45,606

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Project by main and sub-heads.

F. Cross Drainage Works.	G. Bridges.	K. Buildings.	L. Earthwork.	O. Miscellaneous.	P. Maintenance.	Total.
.....	.....	1,57,000	.....	56,000	50,000	27,50,000
.....	.....	.....	.....	.....	13,980	3,30,000
.....	.....	1,57,000	.....	56,000	63,980	30,80,000
.....	.....	.....	.....	.....	.....	18,000
90,400	15,700	.....	1,40,655	.....	.....	3,85,000
41,290	12,320	.....	34,680	.....	.....	94,000
97,780	10,500	.....	71,665	.....	.....	2,02,000
12,380	.....	.....	8,395	.....	.....	31,000
93,340	7,650	.....	29,035	.....	.....	1,41,000
32,960	3,460	.....	35,375	.....	.....	84,000
37,140	2,140	.....	22,405	.....	.....	67,000
12,380	3,670	.....	9,475	.....	.....	33,000
24,760	.....	.....	5,660	.....	.....	33,000
24,760	.....	.....	3,660	.....	.....	31,000
91,320	2,380	.....	30,650	.....	.....	1,50,000
24,760	2,380	.....	4,260	.....	.....	35,000
.....	.....	10,000	.....	.....	.....	10,000
.....	.....	.....	.....	.....	53,000	53,000
5,83,270	60,200	10,000	3,95,915	.....	53,000	13,67,000
.....	.....	.....	.....	.....	.....	10,000
5,480	.....	.....	13,530	3,150	.....	46,000
2,740	960	.....	5,500	1,270	.....	15,000
2,740	.....	.....	9,240	4,150	.....	32,000
.....	2,370	.....	37,750	8,380	.....	82,000
1,500	.....	.....	10,665	2,590	.....	30,000
.....	790	.....	6,745	1,930	.....	17,500
.....	.....	.....	1,460	1,280	.....	10,100
.....	.....	.....	7,090	1,930	.....	22,400
16,440	3,500	.....	56,640	14.870	.....	1.50,000
52,060	1,270	.....	66,225	11,560	.....	1,86,000
.....	960	.....	13,150	3,810	.....	28,000
.....	3,020	.....	54,220	9,930	.....	79,000
.....	.....	5,000	.....	.....	.....	5,000
.....	.....	.....	.....	.....	40,000	4,000
80,960	12,870	5,000	2,82,215	64,850	40,000	7,53,000

Total Works	52,00,000
Establishment	9,25,000
Tools and Plant	60,000
Total Direct Charges . . .	61,85,000

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Data for Rates of Work in the Periar Valley.

I.—Quarrying.

(*a*) Boring by hand-labour working ten hours per day with hand-power drilling machines. Work done—25 feet of hole per day for 900 days =22,500 feet of hole.

Plant—

	£	₹	₹
2 hand-power drilling machines	130	= 1,560	
Carriage to site		100	
Repairs		900	
			2,560

Labour—

⅛ Foreman	225	
¼ Head cooly	225	
1 Picked cooly	600	
2 Ordinary coolies	900	
½ Smith	675	
		2,625

Materials—

1,800 lbs. of steel	900	
Sundries	665	
		6,750

or ₹30 per 100 running feet.

NOTE.—The work estimated for is that of a single drill, but double the number in actual use have to be provided to allow for breakages and repairs.

(*b*) *Dynamite.*—One lb. for every 100 cubic feet of rock removed.

(*c*) *Electrical Firing.*—It has been found impossible to obtain any really trustworthy information as to the cost of the apparatus for electrical firing, but it is believed that for the whole work to be done it cannot amount to more than ₹12,000, which will be covered by a charge of ⅛ rupee on every lb. of dynamite exploded.

(*d*) Removal of rock and loading into wagons where required.

Plant—

	£	₹	₹
6 One-ton cranes	360		
6 Half „	300		
	660	= 7,920	
Carriage to site			2,500
Repairs, &c.			1,000
			11,420

	₹
Or per 100 cubic feet of rock, about	0·28

Labour—

Three coolies one day	1·50
	1·78

Per 100 cubic feet of rock.

	₹
(*a*) Boring 5 running feet at ₹30 per 100	1·50
(*b*) Dynamite 1 lb.	1·75
Detonators and fuze	·50
Tamping	·25
(*c*) Electrical firing	·12
(*d*) Removal of rock	1·78
Sundries	1·60
	7·50

NOTE.—The above rate is for the main escapes and for the watershed cuttings; for the narrow cuttings for the temporary escapes, ₹8 per 100 cubic feet has been allowed.

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II.—Tunnelling.

(*a*) Boring by compressed air. Four drills working 15 hours a day for 900 days; labour in two shifts; work done by each drill 40′ of hole per day.

Plant—

	£	£	R	R
8 rock-boring machines complete	600			
Carriage for 4 machines	80			
Air compressor	150			
Air receiver	50			
Air distributor	45			
Water injector	15			
6,600 feet of 2″ pipe	220			
Guibal fan to exhaust 6,000 cubic feet per minute	60			
Turbine to indicate 60 horse-power with head of 60′, feet, including piping	240			
12 h.-p. portable engine	300			
	540			
Deduct one-third chargeable to transport	180			
		360		
		1,580	= 18,960	
Carriage to site of works			4,000	
Fitting and erection			2,000	
Repairs			8,000	
				32,960

Labour—

1 foreman	1,800	
1 head cooly	900	
4 picked coolies	2,400	
4 ordinary coolies	1,800	
4 smiths	5,400	
		12,300
Working expenses of engine for two months in each season		2,500
6,300 feet of mud wall for ventilating diaphragm		1,575

Materials—

11,520 lbs. of steel	5,760
Sundries	2,505
	57,600

For 900 × 40 × 4=1,44,000 running feet of hole, or R40 per 100 feet.

(*b*) *Dynamite.*—In heading 16 lbs. per 100 cubic feet of rock removed; in enlargement 4 lbs.

(*c*) *Removal of rock.*—6,600 feet of portable railway 2′ gauge

	£	R	R
4 sets points and crossings	500		
6 wagons 30 cubic feet capacity	20		
	90		
	610	=7,320	
Carriage to site		4,000	
Laying line, maintenance and repairs		4,000	
			15,320

Labour—

For loading wagons	8 ordinary coolies.	
For removal	1 to 5 according to distance.	
	9 to 13, average 11	4,950
	Sundries	930
		21,200

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for 5,30,000 cubic feet of rock, or Rs 4 per 100 cubic feet.
Per 100 cubic feet of rock.

		Heading. Boring by air.	Boring by hand.
(*a*)	40 running feet of hole	16·00	12·00
(*b*)	16 lbs. dydamite	28·00	28·00
	Detonators and fuze	6·00	6·00
	Tamping	2·00	2·00
	Electrical firing	2·00	2·00
(*c*)	Removal of rock	4·00	3·00*
	Sundries	7·00	7·00
		65·00	60·00

* The tunnels in which the boring is done by hand are much shorter than the main tunnel, and the removal will cost less.

Enlargement of tunnel—boring by hand.

Boring 20 feet of hole at R30 per 100 feet		6·00
Dynamite 4 lbs. „ 1·75 per lb.		7·00
Detonators and fuze		2·50
Tamping		1·00
Electrical firing		·50
Removal of rock		4·00
Sundries		4·00
		25·00

III.—Concrete.

(*a*) *Lime—*

1,500,000 cubic ft. of limestone at R4 per 100 c. ft.	60,000	
36,000 tons of wood at R2½ per ton	90,000	
		1,50,000
4 Kilns to burn 500 cubic feet each per day	6,000	
Repairs	3,000	
		9,000
3 Head burners	4,050	
9 Burners	5,400	
18 Ordinary coolies	8,100	
		17,550
Sundries		3,450
		1,80,000

For 1,500,000 cubic feet of lime, or R12 per 100 cubic feet—exclusive of transport to site.

(*b*) *Sand—*

R4 per 100 cubic feet, including carriage to site.

(*c*) *Transport of Materials—*

Plant—

	£		
3 Traction engines 10 h.-p. nominal	1,800		
1 Do. 6 do. do.	300		
40 Wagons to carry 6 tons each	3,000		
1 Steamer 10 tons displacement, 25 h.-p.	500		
10 Barges, 18 tons do.	540		
12,000 feet wire rope line to carry 100 tons per day, including rolling-stock, angles and terminal gear	1,700		
One-third cost of watershed turbine and engine	180		
900 feet portable railway, 2-foot guage, for escape quarry	70		
4 Sets points and crossings	20		
2 Turntables	10		
12 Wagons 30 cubic feet capacity	180		
	8,300	= R99,600	
Carriage to site of works		30,000	
Posts for wire rope line		5,000	
Fitting and erection		3,000	
Maintenance and repairs		40,000	
			1,77,600
8,000 tons wood for engines and boats at R2½ per ton		20,000	
Oil, grease, &c.		10,000	
Water-supply		5,000	
			35,000

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Labour—

	R	R
4 Foremen and Engine Drivers	7,200	
6 Artizans and Firemen	8,100	
4 Head coolies	3,600	
4 Picked coolies	2,400	
24 Ordinary coolies	10,800	
		32,100
Sundries		25,300
		2,70,000

For 5,400,000 cubic feet of concrete, or R5 per 100 cubic feet.

(d) Manufacture—

Plant—

	£		
4 stone-breakers 20″ × 9″	1,020		
4 No. 3 disintegrators for lime	440		
4 Mortar mixers	200		
4 concrete mixers	360		
2 elevators 53′ centre to centre	160		
Mortar and stone measurers	60		
100 feet railway 2′ gauge	8		
Two trucks for materials	30		
Pump to throw 5,000 gallons per hour, with pipes	80		
2 water tanks 200 gallons	20		
200 horse-power turbine complete with pipes and gearing to main shaft	540		
Main shaft, belting and gearing	400		
	3,318	= R39,816	
Carriage to site		10,000	
Erection and fitting		6,000	
Maintenance and repairs		15,000	
			70,816

Labour—

1 Foreman	1,800	
2 Artizans	5,400	
2 Head coolies	1,800	
12 Picked coolies	7,200	
10 Ordinary coolies	4,500	
		20,700
Sundries	...	16,484
		1,08,000

or R 2 per 100 cubic feet of concrete.

(e) Construction—

Plant—

3,000 feet wire tramway to carry 200 tons per day, including rolling-stock, angles and terminal gear	£ 800		
Two distributing machines complete	600		
	£1,400	= R16,800	
Carriage to site		4,000	
Fitting and erection		2,000	
Maintenance and repairs		6,000	
			28,800

Working of distributing machines—

600 tons fuel at R2½ per ton	1,500	
Oil, grease, &c.	600	
		2,100

Framing—

3,000 running feet of framing including uprights	12,000	
Repairs and renewals	4,000	
2,500 wrought-iron strap corbels	5,000	
		21,000

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Labour—

1 Foreman	1,800	
6 Artizans	8,100	
4 Head coolies	3,600	
6 Picked coolies	3,600	
16 Ordinary coolies	7,200	
		24,300
Sundries		4,800
		81,000

or R 1·50 per 100 cubic feet of contract.

Abstract per 100 cubic feet.

(a) Lime 25 cubic feet at R 12 per 100 cubic feet	3·00
(b) Sand 30 „ 4 „	1·20
(c) Transport of materials	5·00
(d) Manufacture	2·00
(e) Construction	1·50
Sundries	2·30
	15·00

Rates adopted for minor items.

Earth—removal or cutting	R5	per 1,000 cubic feet.
Timber „	3	„ cubic foot.
Steel „	½	„ lb.
Wrought-iron	¼	„ „
Cast-iron	⅛	„ „
Pisé work for walls of buildings	10	„ 100 cubic feet.
Roofing with bamboos and thatch	10	„ square.
Whitewashing walls of buildings	4	„ „
Plastering for main dam	10	„ „

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TABLE No. I.

Dimensions, Pressures, &c., in main dam.

Depth below maximum water level.	Front slope.	Rear slope.	Total width.	Area of section.	Reservoir empty.		Reservoir full to 70′ from top.		Reservoir full.		
					Distance of line of pressure from front face.	Pressure on front face.	Distance of line of pressure from front face.	Pressure on front face.	Distance of line of pressure from rear face	Pressure on rear face.	
										At flanks.	At centre.
Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	lbs. per sq. ft.	Feet.	lbs. per sq. foot.	Feet.	Pounds per square foot.	
Parapet.	8	12	4	...	2·00	...	2·00	...	2·00	...	...
0	0	12	12	20	10·00	703	10·00	703	2·00	703	703
10	0	12	12	140	6·57	1,171	6·57	1,171	4·90	2,543	2,663
20	0	14	14	270	6·54	3,243	6·54	3,243	5·25	4,732	5,470
30	0	18	18	430	7·10	5,482	7·10	5,482	6·25	6,441	8,017
40	0	24	24	640	8·24	7,276	8·24	7,276	8·35	7,169	9,419
50	½	30½	31	915	10·34	8,296	10·34	8,296	10·76	8,047	10,863
60	1	37	38	1,260	12·68	9,318	12·68	9,318	13·05	9,198	12,622
70	1½	43½	45	1,675	15·12	10,341	15·12	10,381	15·34	10,455	14,539
80	2	50	52	2,160	17·63	11,485	17·66	11,474	17·68	11,758	16,354
90	2½	57½	60	2,720	20·22	12,610	20·42	12,510	20·93	12,478	17,771
100	3	68	71	3,375	23·11	13,680	23·65	13,424	27·11	11,738	17,805
110	3½	78½	82	4,140	26·38	14,697	27·41	14,223	33·65	11,408	17,847
120	4	87½	91½	5,007½	29·79	15,825	31·50	14,986	37·64	12,129	17,827
130	4½	95	99½	5,962½	32·96	16,958	35·42	15,818	40·86	13,312	17,866
140	5	101½	106½	6,992½	36·16	18,125	39·59	16,505	43·17	14,785	17,900
150	5½	107½	113	8,090	39·16	19,335	43·58	17,176	44·81	16,612	17,830
155	5¾	110	115¾	8,663¾	40·59	19,958	45·43	17,473	45·28	17,893	17,893

TABLE No. II.

Dimensions, &c., on escape dam on left bank.

	Front slope.	Rear slope.	Total width.	Area of section.	Distance of line of pressure from rear face.	
					Reservoir empty.	Reservoir full to 12′ above crest of escape dam.
	Feet.	Feet.	Feet.	Sq. Feet.	Feet.	Feet.
Top	9	0	9	...	4·50	4·50
5 feet below top	12½	½	13	55	5·80	5·89
10 „ „ „	16	1	17	130	7·15	6·86
15 „ „ „	19⅓	1½	21	225	8·55	7·85
20 „ „ „	23	2	25	340	9·97	8·86
25 „ „ „	26⅓	2½	29	475	11·41	9·91
30 „ „ „	30	3¼	33¼	630⅝	13·08	11·22
35 „ „ „	30	5½	35½	802½	15·64	11·84
40 „ „ „	30	8½	38½	987½	18·63	12·86

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TABLE No. III.

Area of lake surface and capacity of lake at various levels.

Level.	Area.	Capacity	Level.	Area.	Capacity.	Level.	Area.	Capacity.
Feet.	Millions of square feet.	Millions of cubic feet.	Feet.	Millions of square feet.	Millions of cubic feet.	Feet.	Millions of square feet.	Millions of cubic feet.
10	1·8	6	85	94·8	2,890	146	287·0	13,864
15	3·9	20	90	105·3	3,390	147	291·2	14.153
20	7·5	49	95	117·4	3,947	148	295·4	14,447
25	11·1	95	100	130·8	4,567	149	299 6	14,744
30	14·7	159	105	143·6	5,223	150	303·8	15,046
35	18·3	242	110	156 4	6,003	151	308·0	15,352
40	23 2	346	(a) 113	164·0	6,484	152	312·2	15,662
45	30·1	479	115	171·2	6,819	153	316·4	15,976
50	36·9	647	120	189·1	7,720	154	320·5	16,295
55	43·8	848	125	207·0	8,710	(c) 155	324·7	16,617
60	50·7	1,085	130	224·8	9,789	156	328·9	16,944
65	58·5	1,358	135	242·7	10,958	157	333 1	17,275
70	67·5	1,673	140	261·8	12,218	158	337·3	17,610
75	76·6	2,033	(b) 144	278·6	13,299	159	341·5	17,950
80	85·7	2,439	145	282·8	13,579	160	345·7	18,293

(a)—Level of sill of watershed cutting.
(b)— „ „ crest of escape.
(c)—Maximum water level.

TABLE No. IV.

Rise of lake during flood similar to that of 17th—19th November 1869.

Level of lake surface.	Discharge from lake.			Discharge of river.	Stored in lake.	Capacity of lake.	Time occupied in filling.	Total duration.
	Through tunnel.	Over escape.	Total.					
Feet above datum.	Millions of cubic feet per hour.					Millions of cubic feet.	Hours.	Hours
144 to 145 . . .	6	5	11	130	119	280	2·35	6·50
145 to 146 . . .	6	22	28	130	102	285	2·73	
146 to 147 . . .	6	45	51	130	79	289	1·42	1·00
				209	158		1·00	
				243	192		·10	1·00
147 to 148 . . .	6	75	81	243	162	294	·90	
				272	191		·73	1·00
148 to 149 . . .	6	109	115	272	157	297	·27	
				294	179		1·00	1·00
				291	176		·43	1·00
149 to 150 . . .	6	148	154	291	137		·57	
				251	97		1·00	1·00
				200	46		1·00	1·00

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TABLE No. IV.—(*continued*).

Level of lake surface.	Discharge from lake.			Discharge of river.	Stored in lake.	Capacity of lake.	Time occupied in filling.	Total duration.
	Through tunnel.	Over escape.	Total.					
Feet above datum.	Millions of cubic feet per hour.					Millions of cubic feet.	Hours.	Hours.
				153	— 1		1·00	1·00
				118	—36		—	
							1·00	1·00
149 to 150	6	148	154	105	—49	302	—	
							1·00	1·00
				118	—36		—	
							1·00	1·00
				315	161		—	
							1·26	3·50
				315	121		2·24	
150 to 151	6	188	194			306	—	
				531	337		·12	1·00
							—	
				531	292		·88	
151 to 152	6	233	239			310	—	
				516	277		22	1·00
							—	
				516	234		·78	
152 to 153	6	276	282			314	—	
				457	175		·67	1·00
							—	
153 to 153·15	6	308	314	457	143	47	·33	
							—	
153·15	6	311	317	309	—	Falls.	...	

TABLE No. V.

Average maximum and minimum discharges during each month from July to February.

MONTH.	Cubic feet per second.						
	Average.					Maximum.	Minimum.
	1869-70.	1870-71.	1871-72.	1872-73.	Mean.	In four seasons.	
July	1,085	...	2,980	...	2,032	13,110	522
August	1,235	...	864	1,195	1,098	7,272	425
September	842	...	812	1,266	973	5,845	425
October	857	1,344	941	582	931	7,644	347
November	6,205	1,525	1,531	...	3,088	1,27,129	404
December	1,212	554	689	...	818	12,874	311
January	680	1,207	335	...	741	12,994	270
February	342	372	311	...	342	731	200

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TABLE No. VI.

List of freshes exceeding 414·72 millions of cubic feet in twenty-four hours, with their effect towards topping the work at various stages.*

DATE.	Discharge in 24 hours millions of c. ft.	First season.		Second season.		Third season.		Fourth season.	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
July 1871—18th to 21st . . .	928	...	...	513	3·13	313	2·62	...	...
Oct. 1869—29th	415	203	...	203	...	...	...	...	...
Nov. 1869— 7th to 8th	641	333	2·25	317	2·05	...	12·27	1,185	...
„ 1869—17th to 19th	5,705	3,421	20·69	3,256	17·31	2·759	...	...	7·30
„ 1870—15th	686	360	2·40	342	2·19	...	...	...	...
„ 1870—19th	445	221	...	203	...	...	...	...	...
Jan. 1871—14th	464	231	...	167	...	...	...	...	...

a.—Area in square feet of escape culvert necessary to prevent submersion of the work.

b.—Depth in feet to which the work would be submerged with escape culverts aggregating 240 square feet as now proposed.

* 4,800 cubic feet per second for 24 hours.

TABLE No. VII.

Estimate of rainfall in the Periar Valley.

MONTH.	Average recorded rainfall at				Average depth run off from Periar catchment in 1868-72.	Estimated rainfall at 1·8 depth run off.	Depth run off.	Rainfall.
	Cochin.	Trevandrum.	Angustermully.	Average.			To give the discharges entered in Column 4 of Table VIII.	
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January	·34	·56	6·23	2·38	2·92	5·26	2·86	5·15
February	·65	·39	2·28	1·11	1·54	2·77	1·15	2·07
March	1·93	1·91	3·18	2·34	...	...	1·24	2·23
April	5·30	5·48	7·41	6·06	...	...	2·15	3·87
May	13·34	8·87	30·66	17·62	...	...	5·74	10·33
June	28·05	11·84	28·64	22·84	...	...	7·17	12·91
July	22·47	8·28	30·96	20·57	7·81	14·06	7·17	12·91
August	12·77	6·11	21·86	13·58	4·22	7·60	4·16	7·49
September	8·48	4·44	16·46	9·79	3·63	6·53	3·59	6·46
October	12·63	10·05	26·04	16·24	3·29	5·92	3·16	5·69
November	4·32	5·56	15·58	8·49	11·34	20·41	7·17	12·91
December	·88	1·52	9·72	4·01	3·18	5·72	3·01	5·2
Total .	111·16	65·01	199·02	125·03	—	—	48·57	87·44

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TABLE No. VIII.

Estimate of water available for irrigation.

MONTH.	Average discharges as gauged in 1868 to 1872.	Discharge from 300 square miles, at 4th of the depths in Column 5 of Table VII.	Estimated discharge.	Loss by evaporation.		Balance available for irrigation.
				On Periar lake.	In beds of Sooroolly and Vigay.	
	Millions of cubic feet.					
January	2,020	921	2,000	150	100	1,750
February	836	430	800	180	90	530
March	...	9 5	900	220	90	590
April	...	2,346	1,500	220	...	1,280
May	...	6,822	4,000	180	(b) 590	3,230
June	...	8,844	4,000 (a)	110	80	3,810
July	5.440	7,965	4,000 (a)	80	100	3,820
August	2,941	5,259	2,900	110	100	2,690
September	2,525	3,791	2,560	150	90	2,260
October	2,294	6,288	2,200	110	80	2,010
November	8,002	3,287	6,000	110	80	5,810
December	2,193	1,553	2,100	120	90	1,890
TOTAL	—	48,411	32,900	1,740	1,490	29,670

(a) The discharge during these months will exceed 4,000 millions of cubic feet, but a portion may be lost by discharge over the escape.

(b) 500 millions are allowed for filling the beds of the Sooroolly and Vigay

	Cubic feet.
Amount required for 90,000 acres of first crop	16,200 millions.
„ „ „ 60,000 „ „	9,600 „
	25,800

TABLE No. IX.

State of reservoir when irrigating 90,000 acres of first crop and 60,000 of second crop.

MONTH.	Stored above sill of cutting at the beginning of the month.	Received during month.	Total of Cols. 2 and 3.	Lost by evaporation.	Used for irrigation.	Total of Cols. 5 and 6.	Balance in reservoir at end of month.
	Millions of cubic feet.						
May	...	4,000	4,000	770	600	1,370	2,630
June	2,630	4,000	6,630	190	2,400	2,590	4,040
July	4,040	4,000	8,040	180	3,600	3,780	4,260
August	4,260	2,900	7,160	210	3,600	3,810	3,350
September	3,350	2,500	5,850	240	3,600	3,840	2,010
October	2,010	2,200	4,210	190	1,800	1,990	2,220
November	2,220	6,000	8,220	190	1,800	1,990	6,230
December	6,230	2,100	8,330	210	2,400	2,610	5,720
January	5,720	2,000	7,720	250	2,400	2,650	5,070
February	5,070	800	5,870	270	2,400	2,670	3,200
March	3,200	900	4,100	310	1,200	1,510	2,590
April	2,590	1,500	4,090	220	...	220	3,870
TOTAL	—	32,900	—	3,230	25,800	29,030	—

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STATEMENT No. I.

Probable progress of main dam towards completion.

MONTH.	1st season.			2nd season.			3rd season.			4th season.			5th season.		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
July . . .	...	...	...	22	137	23	23	330	49	25	527	76	25	725	110
August . . .	...	...	...	25	162	27	25	355	52	25	552	79	25	750	116
September . .	...	...	...	25	187	30	25	380	55	25	577	83	25	775	123
October . . .	20	20	2	25	212	33	25	405	58	25	602	87	25	800	131
November . .	20	40	7	20	232	36	23	427	61	23	625	91	25	825	140
December . .	25	65	12	25	257	40	25	452	65	25	650	95	25	850	150
January . .	25	90	16	25	282	43	25	477	68	25	675	100	25	875	150
February . .	25	115	20	25	307	46	25	502	72	25	700	105	25	900	160

(*a*)—Number of working days in month allowing for interruptions.
(*b*)—Total number of working days since beginning of work.
(*c*)—Level to which main dam is completed at end of month.
When the main dam is completed to 150 feet, which will be in December of the fifth season, the left bank escape dams will be put in hand and completed before the upper five feet and parapet of the main dam are put on.
Average quantity of concrete to be executed per day . . . **5,921** cubic feet.

STATEMENT II.

Labour required for the Head Works in the Periar Valley.

Nature of works.	Foremen.	Artizans.	Head coolies.	Picked coolies.	Ordinary coolies.
Quarrying	2	4	2	8	130
Tunnelling	2	6	2	8	24
Lime burning	...	3	...	9	18
Collecting sand	...	...	2	4	60
„ firewood	...	...	2	4	80
Transport	4	6	4	4	24
Manufacture of concrete	1	2	2	12	10
Construction of dam	1	6	4	6	16
Maintenance of road	...	2	2	...	24
Repairs of plant	1	15	10	10	29
Sundries	1	6	5	10	44
TOTAL . .	12	50	35	75	450

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STATEMENT No. III.

Establishment required for the supervision of the works.

No.	Rank.	Salary for twelve months.	Personal allowance for nine months.	Total per annum.	
	HEAD WORKS.	₹	₹	₹	
	Preliminary year.				
1	Assistant Engineer	5,400	1,350	6,750	
2	Overseers	1,920	540	2,460	
3	Clerks	1,800	450	2,250	
8	Peons and lascars	960	...	960	
1	Hospital Assistant	960	270	1,230	
	Total	...	...	13,650	For one year.
	Years of regular construction.				
1	Superintending Engineer*	19,200	2,700	21,900	*For general supervision, but will be chiefly employed on the head works.
1	Executive Engineer	7,800	1,800	9,600	
2	Assistant Engineers	9,600	3,600	13,200	
1	Mechanical Engineer	6,000	...	6,000	
1	Sub-Engineer	4,800	900	5,700	
1	Supervisor	2,400	540	2,940	
5	Overseers	4,800	1,350	6,150	
2	Accountants	2,400	600	3,000	
7	Clerks	4,200	1,050	5,250	
2	Draftsmen	1,200	300	1,500	
40	Peons and lascars	4,800	...	4,800	
3	Store-keepers	1,440	360	1,800	
2	Medical subordinates	2,400	600	3,000	
	Total	...	...	84,840	For five years.
	Work in plains.				
1	Executive Engineer	9,600			
3	Assistant Engineers	15,000			
1	Sub-Engineer	3,600			
1	Supervisor	2,400			
6	Overseers	5,760			
2	Accountants	2,400			
8	Clerks	4,800			
2	Draftsmen	1,200			
20	Peons and lascars	1,680			
2	Storekeepers	960			
	Total	47,400	...	...	For five years.

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STATEMENT No. III.—*(continued.)*

Establishment required for the supervision of the works.—(contd.)

No.	Rank.	Salary for twelve months.	Personal allowance for nine months.	Total per annum.	
		R	R	R	
	R 13,650 for one year . . .	13,650			
	„ 84,840 for five years . . .	4,24,200			
	„ 47,400 for five years . . .	2,37,000			
			6,74,850		
	Allowance to an officer in England for superintending purchase of machinery, &c.	...	12,000		
	Travelling allowances	...	80,000		
	Contingencies	...	20,000		
	Stationery	...	20,000		
	Total .	...	...	8,06,850	

Amount provided in estimate.

Total cost of works			52,00,000
Deduct—			
Cost of land	9,83,820		R
„ „ plant and machinery to be obtained from England .	2,50,000		12,33,820
			39,66,180
23 per cent. on R39,66,180			9,12,221
Allowance to an officer in England, &c.			12,000
			9,24,221, say R9,25,000.

STATEMENT No. IV.

Provision in estimate on account of "Tools and Plant".

		R
Total cost of works		52,00,000
Deduct as in Statement IV		12,33,820
		39,66,180
1½ per cent. on R39,66,180		59,493, say R 60,000.

STATEMENT No. V.

Capitalization of abatement of land revenue.

Acres.	Assessment.	Amount.		
		R	a.	p.
169 at R	5 14 3	995	8	3
1,182 „	1 5 0	1,551	6	0
109 „	2 0 0	218	0	0
745 „	0 14 0	651	14	0
	Total .	3,416	12	3

R3,416 capitalized at twenty-five years, purchase=R85,419.

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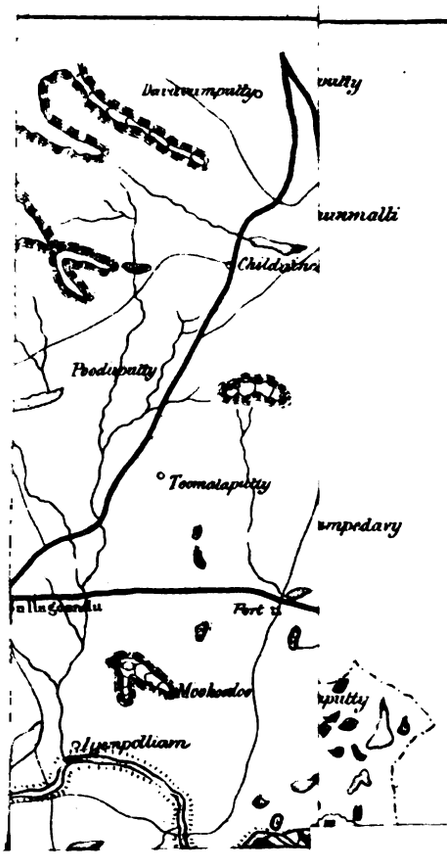

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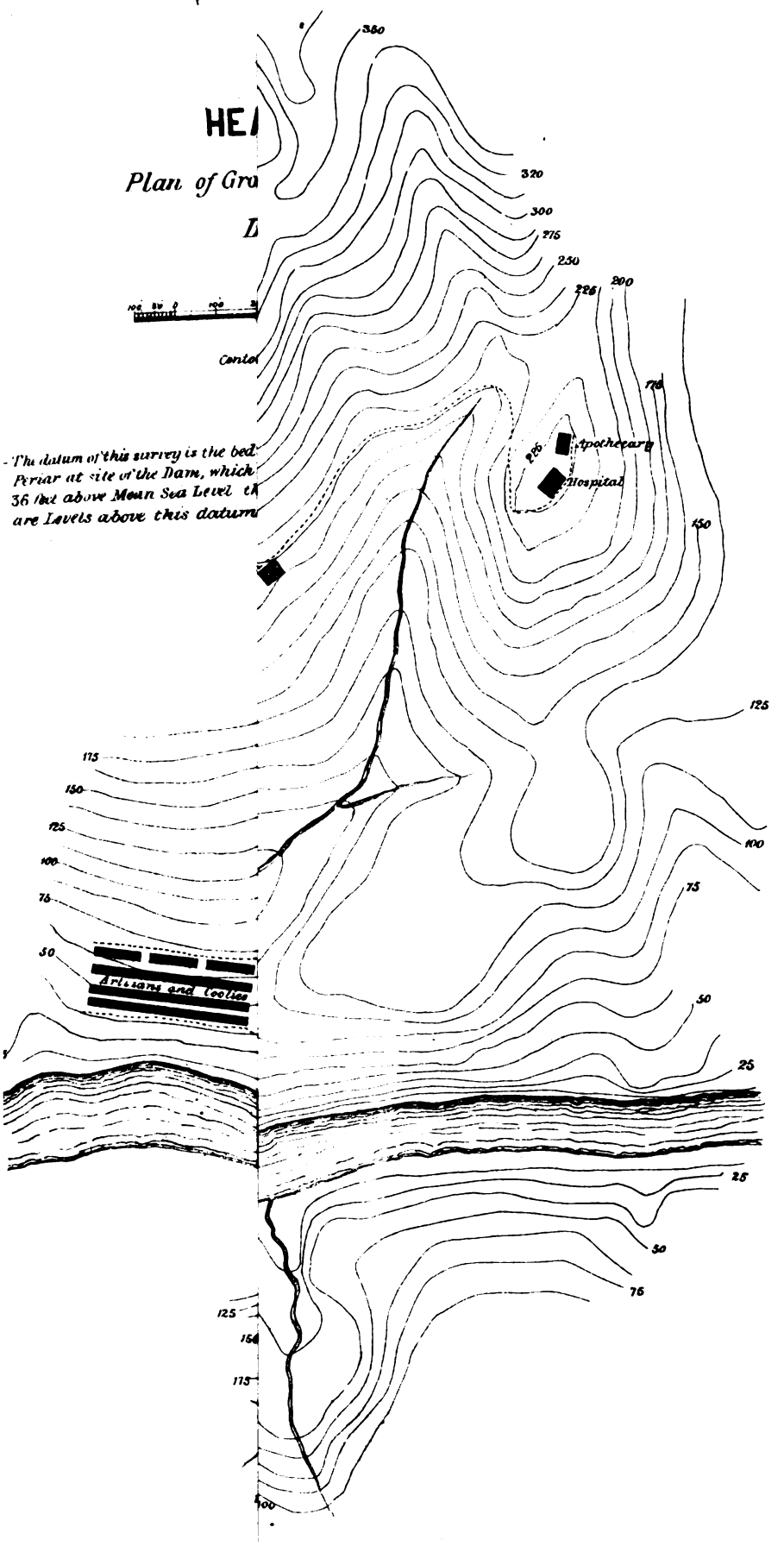

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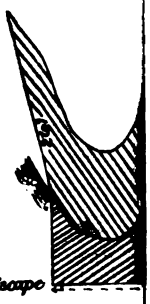

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Superintending Engineer
for 1868 on Special duty

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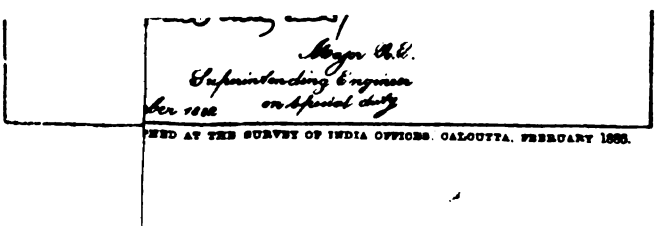

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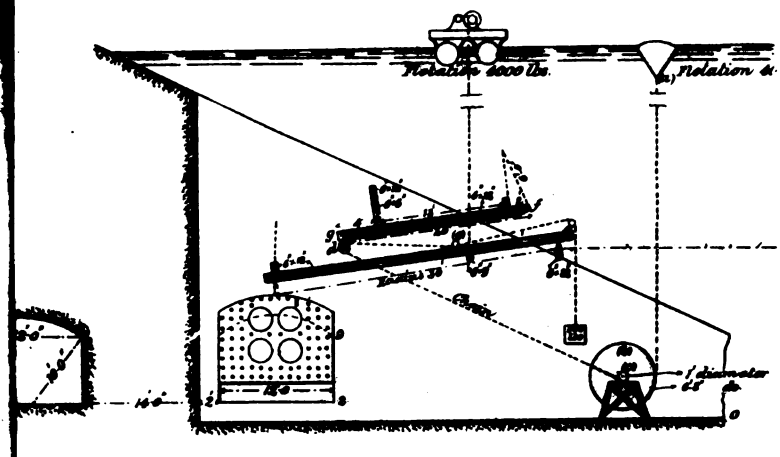

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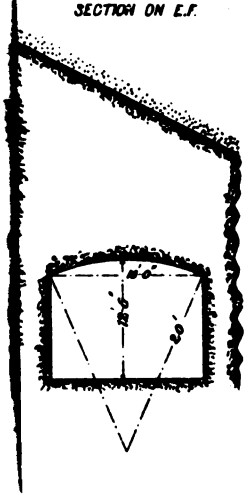

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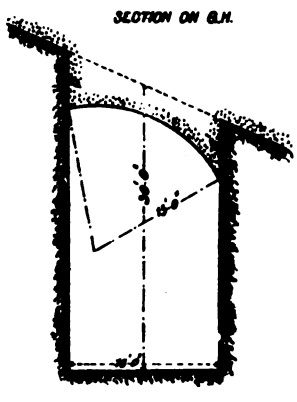

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Major R.E.
Superintending Engineer
ber 1862 on Special duty

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On special duty.

Major R.E.
Superintending Engineer
Dec 1882 on Special duty

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12
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12

NK ESC.

1000 feet above
mouth of Cutlee

On special duty.

Major R.E.
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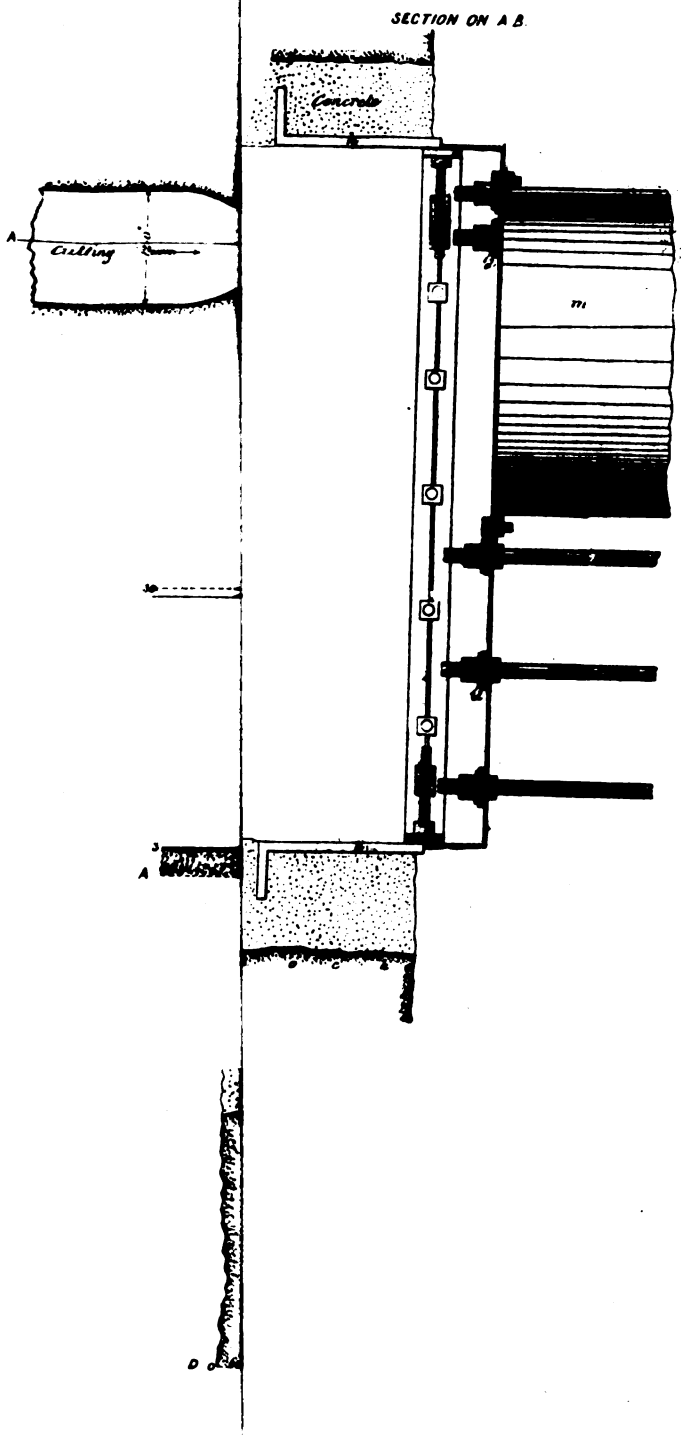

1000 feet to
breath of Cuttak

On special duty.

Major R.E.
Superintending Engineer
ber 1862 on Special duty

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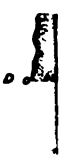

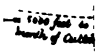

On special duty.

Major R.E.
Superintending Engineer
Dec 1862 on Special duty

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Assistant Engineer
On special duty.

Major R.E.
Superintending Engineer
Dec 1862 on Special duty

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Executive Engineer
On special duty.

Major R.E.
Superintending Engineer
for 1868 on Special duty

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Assistant Engineer
On special duty.

Major R.E.
Superintending Engineer
ber 1862 on Special duty

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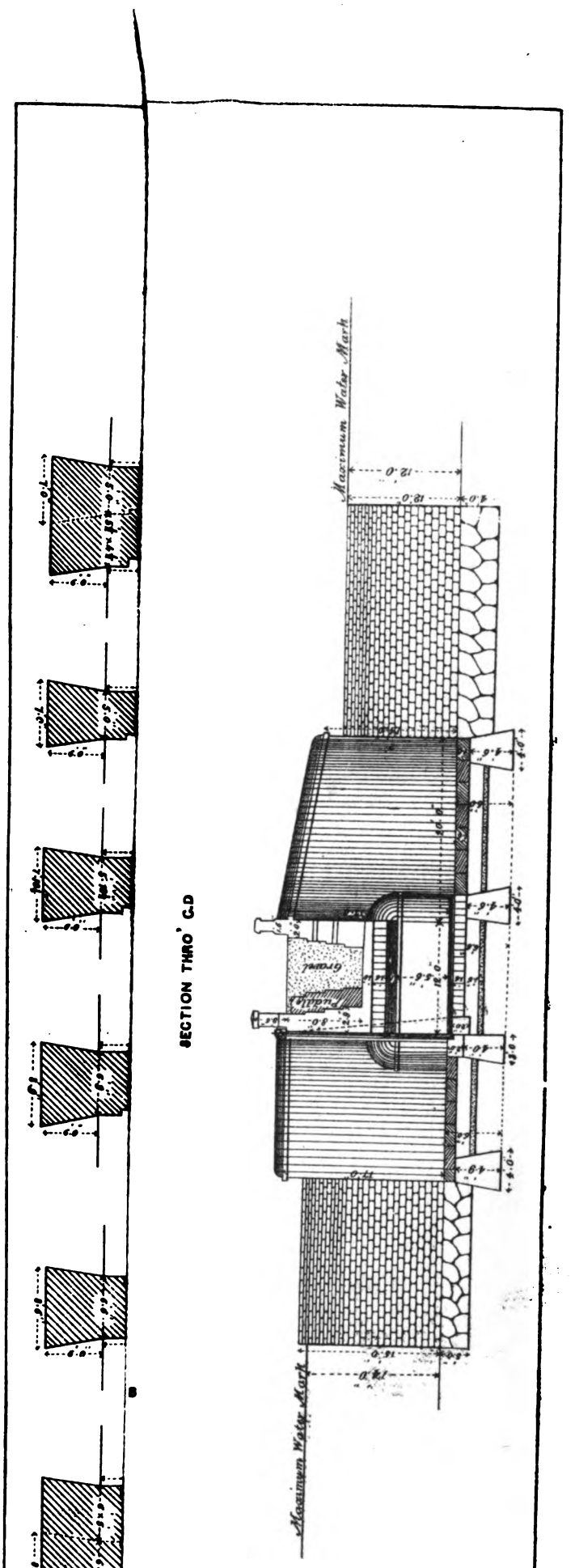

Signed/ R. Smith.
Executive Engineer
On special duty.

Major R.E.
Superintending Engineer
for 1882 on Special duty

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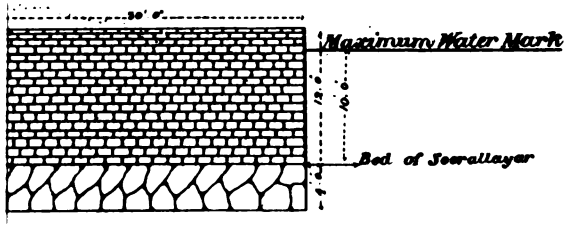

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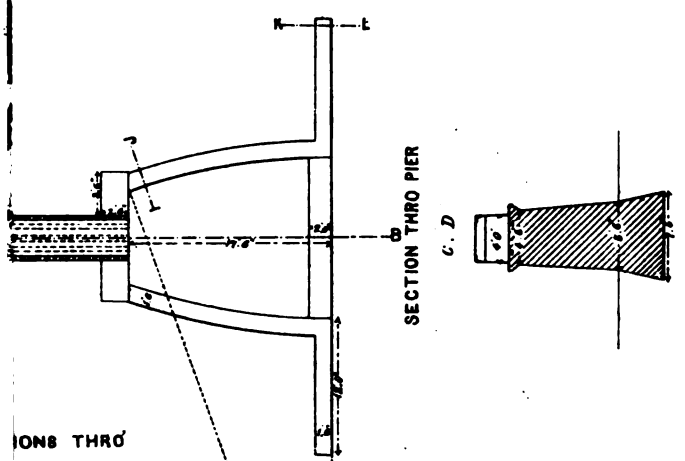

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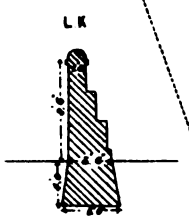

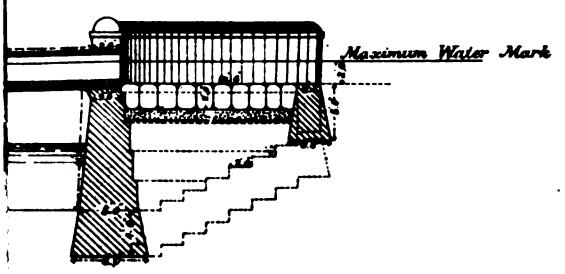

(Sd) Major R E
Supt. Engr. on Special Duty

(Signed) R. Smith
Executive Engineer
On Special Duty

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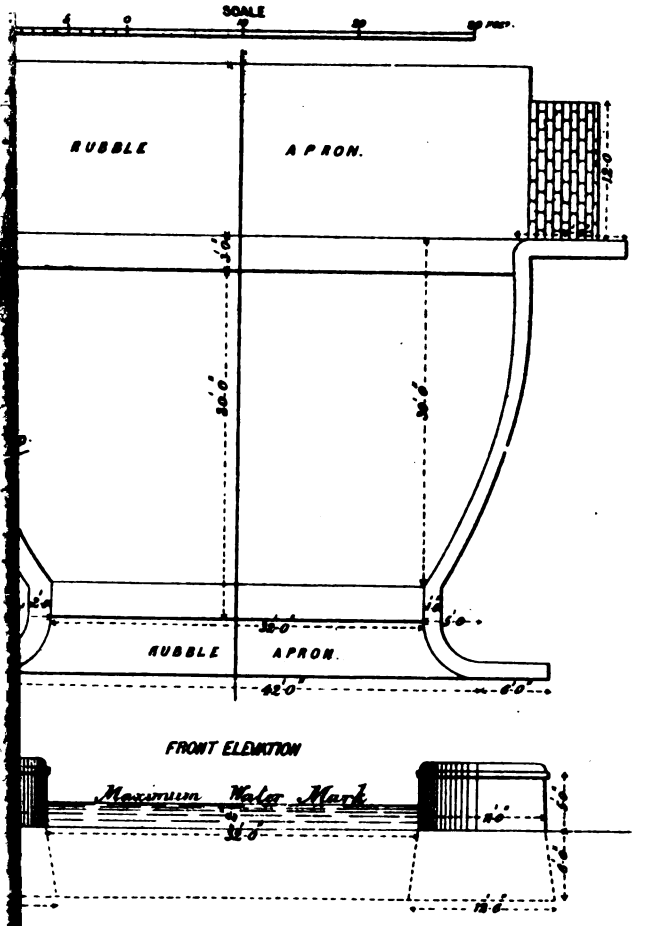
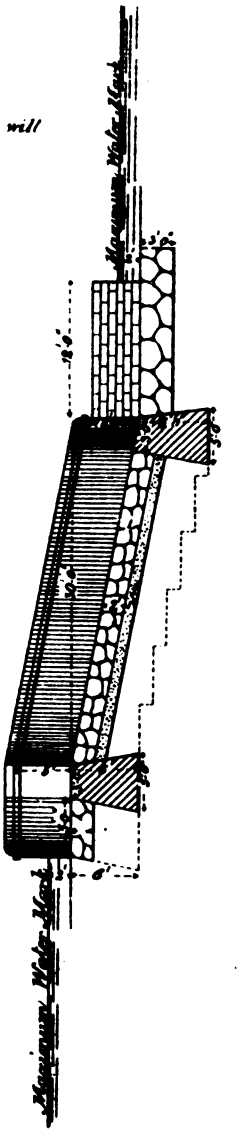
GENERAL PLAN FOR FALLS OF 6 FEET IN THE MAIN DISTRIBUTION CHANNELS

Note. The length of the Body will will vary to suit the discharge.



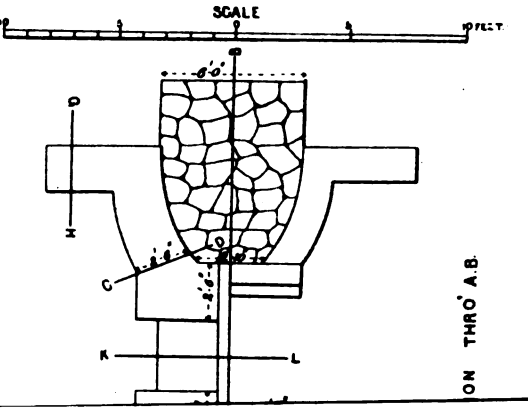


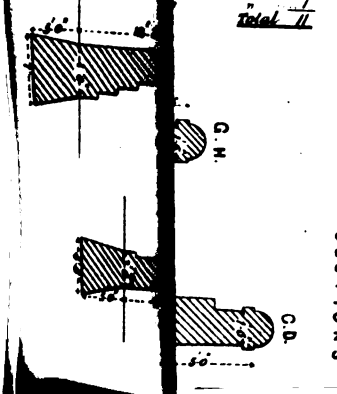
SECTION THRO' A.B.

GENERAL PLAN OF IRRIGATION SLUICES

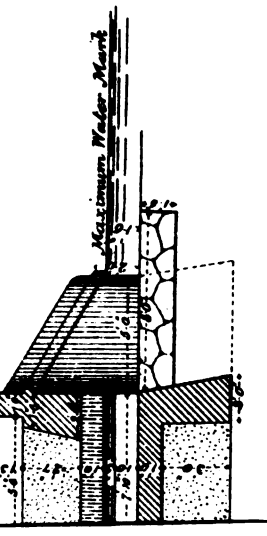
FOR PLOTS

NOT EXCEEDING 50 ACRES





SECTIONS



ON THRO' A.B.

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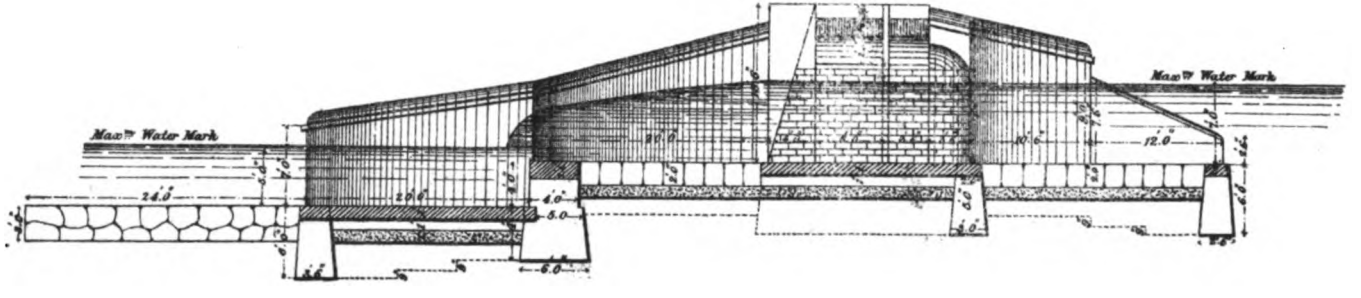
CROSS SECTION THRO C. D.



NOTE. In execution the faces and spaces in front of grooves should be lowered by 4".

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No. 233—90, dated Caroor, 17th July 1876.

From—H. F. CLOGSTOUN, Esq., Acting Deputy Director of Revenue Settlement, Coimbatore,

To—The Acting Director of Revenue Settlement.

In compliance with the Order of Government contained in their Proceedings No. 1236, dated 16th August 1875, I have the honor to submit a report on the probable result, on a financial point of view, of the construction of the Periar tank and channels for the irrigation of a portion of land in the Madura district in the mode proposed by Colonel Oakes in a memorandum, dated the 20th January 1873, No. 28.

2. The district of Madura is so situated that, even supposing a famine to occur simultaneously in the large rice-growing district of Trichinopoly, Tanjore, and Tinnevelly, all of which are within a few hours' rail of the town of Madura, the country could be deluged in a fortnight to its furthest corners with rice from Bengal, from the Godavery, or from Burma. As the construction, therefore, of so costly a work of irrigation[1] can hardly be considered a work of necessity for the protection of the country from famine, and as therefore, in the present state of the finances of India, its construction must depend on the promises it may hold out of realising a return proportioned to the large expenditure incurred on it, I shall not waste any time in dwelling in general terms on the advantages which the district may be expected to derive from the work. These advantages are manifest to any one who realises the difference between the produce of an acre of unirrigated land and that of an acre of irrigated land in Southern India, and they will be fully weighed when treating in a later portion of this paper of the value to the Madura ryot of a certain supply of water.

3. The conduct of the inquiry entrusted to me has involved the carrying out of the following processes :—

(1) The classification and grain valuation of all Government lands irrigable by the project, and a determination of the probable cost of cultivation of the same lands with rice, the grain to which irrigated land is almost exclusively devoted, in view to arriving at the surplus produce, or the profits on cultivation, available for division between the Government and cultivator in such proportions as may be deemed advisable.

(2) The determination of a commutation rate and of an assessment which, while rendering the cultivation of rice so advantageous to the ryots as to ensure as far as can be foreseen that irrigation shall be in great demand, shall yet give to Government a fund sufficient to guarantee a fair profit on any reasonable expenditure in providing this irrigation.

(3) The selection from the whole area commanded by the channels of that land to which water may be most advantageously supplied, as also of the area on which it may be advisable to permit the growth of second crop in preference to extending the area of single-crop cultivation.

In the concluding portion of the report, I shall treat of the probable length of time required to bring under wet cultivation the large area, 150,000 acres, which the channels are capable of irrigating, and perhaps offer a few remarks upon the general state of the district, and upon any circumstances within my knowledge connected with the customs or habits of the ryots, or with the nature and quality of the lands of the district, which may tend, prejudicially or otherwise, to affect the success of the project.

4. I shall treat of the various processes alluded to above in the order in which I have named them, and I trust that the magnitude of the issues at stake will be my excuse if I dwell with apparently unnecessary length on the evidence I adduce as warranting the conclusions at which I arrive. I may add that much of the information acquired during the conduct of this inquiry will be of advantage in aiding the determination of a suitable assessment for the district when the present Revenue Settlement comes under revision, as it shortly will, and that the time spent in the district cannot, therefore, be considered lost even should the project be abandoned.

5. REGARDING THE CLASSIFICATION AND GRAIN VALUATION OF THE TRACT TO BE IRRIGATED—The classification and grain valuation have been confined to that tract on the north of the river Vigay to which, in Colonel Oakes' Memorandum, it is proposed to confine the irrigation I shall have to advance in a later portion of this paper reasons which seem to me to render it advisable that the irrigation should not be so restricted; but I have not thought it necessary at present to extend the work of classification. That portion of the work already carried out appears to me to furnish sufficient evidence that an assessment, at least as high as was anticipated by the Public Works Department, can be obtained for any land to which the water is

[1] The latest estimate puts the cost of the work at £600,000 or £700,000 according as the distribution channels are confined to the north bank or extended to both banks of the Vigay river.

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likely to be furnished. I should explain further that classification has been confined to ryotwari villages, for it is on this class of land only that the assessment can with advantage be graded according to the productive qualities of the soils. In the inam or zemindari villages, a fixed charge for water must continue to be levied.

6. The classification of the lands in ryotwari villages commanded by the Periar channels has been carried out on the simple system which obtains in the Settlement Department. It involves a division of the soils into their easily-recognised classes, of black or red loam, black or red or white sand, black or red clay, &c., and a valuation of each of these classes in terms of a staple grain on the basis of actual experiments made to test their productive powers. Each of the main divisions is divided into sorts according to the quality of the soil. I have, in the present case, chosen five sorts for each soil; but as the last two sorts were from an early date set apart for all those very poor lands which it seemed impossible could pay an assessment of Rs. 5-8-0 per acre, and which, therefore, I propose, if possible, for reasons to be hereafter explained, to exclude from irrigation, there remained virtually only three sorts in which any land to be brought under the project could be placed. The difficulty of classification lies in the fair distribution of land into these different sorts. Classification is not an exact science, and there is therefore much scope for error in its performance; but as under all the new settlements it is based to as large an extent as is possible on actual experiments, it is clear that little is left undone to make it as accurate as it is possible to make it. I have laboured under the disadvantage in Madura of having to value as rice-producing land a tract which is at present producing dry crops only. I have, however, taken as my guide the results of experiments made during the year to test the yield on similar land in Madura irrigated by the Vigay river which rises near the sources of the Periar, and also of experiments made under my supervision in Coimbatore in previous years to test the yield of paddy on lands in that district irrigated by the Noel, Bowani, and Cauvery rivers. That the amount of the outturn on wet lands is as largely dependent on the system of cultivation as on the quality of the soil and of the water-supply is clear from a comparison of the experiments made by Mr. Rundall in the villages in Nellore, irrigated by the Penniar anicut, with those made under my orders in Coimbatore. In Nellore, where the water-supply is excellent, and the soil, I believe, of fair quality, the average yields obtained by experiments are very considerably below those obtained in Coimbatore; but it seems clear from the report of Mr. Thornhill [1] that the poverty of yield in Nellore is due to the inferior method of cultivation in vogue in the district, and as the system of cultivation in Madura is similar to that prevailing in Coimbatore, I do not think that the results of the experiments under the Nellore anicut need stand in our way in fixing on the wet lands of the former district a grain valuation and an assessment pitched considerably higher than the Nellore experiments would seem to warrant. Wet cultivation seems thoroughly well understood in all the neighbouring districts of Madura, and is certainly very efficient in the parts of that district itself, which are at present irrigated by anicut channels.

7. I have spoken of the classification and grain valuation together, for the latter is merely the complement of the former. The terms black loam of the first sort and black loam of the second sort convey no information; but when black loam of the first sort is explained to mean black loam rated at a productiveness of 1,200 Madras measures per acre, and black loam of the second sort to be such as will yield about 900 Madras measures per acre, the distinction intended between the two is at once grasped.

8. The soil of the tract on the north of the river Vigay commended by the Periar channel consists mainly of a black sandy loam in the Madura taluq, which in parts, especially where the land is flat and low-lying, is largely intermixed with salts of a kind which may be very hurtful to wet crops unless the tract is carefully drained. In the Melur taluq the nature of the soil changes, and a rich red sandy loam is found to prevail, of the value of which, as rice land, I have formed a very high opinion. In the Melur taluq moreover the land is undulating, and can therefore be drained with great ease, while there appears to be much less of such salts in the soil as render a careful drainage necessary.

9. The classification has been carried out under the "block system" so earnestly advocated by Mr. Puckle, and I must admit that it is a system excellently adapted for the classification of a large tract of irrigated land, or of land, as in the present case, about to be brought under irrigation. Water, speaking generally, so largely enhances the productiveness of all lands, that minor inequalities of soil do not call for notice under a large scheme of assessment where

[1] *Vide* letter to Secretary to Government, No. 185, dated 20th March 1874, printed with Proceedings, Madras Government, dated 16th October 1874. Mr. Thornhill was inquiring regarding the alleged oppressiveness of the new assessment on anicut irrigated lands. This assessment averaged only Rs. 5-13-11 per acre, and was less by 35 per cent. than that paid for a single crop on the Cauvery irrigated lands in Salem, and by from 50 to 80 per cent. than that prevailing under the two Bowani channels in Coimbatore, where nevertheless the average selling price of wet land is upwards of Rs. 200 per acre.

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a large margin of possible profit above the assessable maximum must always be left to the ryot. A difference of one rate in a scale of wet assessments means, perhaps, that a general profit of 300 Madras measures per acre, and a possible and not improbable profit of 800 Madras measures is lessened by about 30 measures. Under none of the recent settlements has wet land ever been valued for assessment purposes at about an average outturn of 1,000 Madras measures per acre,[1] though a yield of 2,000 measures is not unknown in a good season, and an outturn in excess of 1,500 measures is very frequently attained. I have stated that the block system employed in the classification of wet lands cannot seriously hurt the ryot when it raises his assessment slightly above what it might be under the fieldwar system of classification. But, the block system is at least as potent an engine for 'levelling down' as for 'levelling up' assessments, and the owners of wet land are pretty safe to come off liberally treated if the system is worked with discretion. I trust that, while using, I have not abused, the system, and I may say that every care has been shown to attain as just a classification as possible for individual fields as well as for the tract generally.

10. The result of the classification is shown in the subjoined statement. The work in very village has been illustrated by a rough map of the soils prevailing in it:—

[1] The maximum grain valuation is generally 1,200 Madras measures per acre, but a deduction is always made for vicissitudes of season. This deduction is not generally less than one-fifth.

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Particulars of soils.	Description of soils.		MADURA.					MELUR.					TOTAL.					GRAND TOTAL.		
			Government.			Inam.		Government.			Inam.		Government.			Inam.		Government and Inam.		
	Class.	Sort.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.
			Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Clay	3	1	26	...	26	3	...	...	...	...	...	...	26	...	26	3	...	29	...	29
		2	15	...	15	6	...	...	...	...	...	...	15	...	15	6	...	21	...	21
		3	12	...	12	3	...	...	...	...	...	...	12	...	12	3	...	15	...	15
		4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Total	...	53	...	53	12	...	...	...	...	...	...	53	...	53	12	...	65	...	65
Black Loam	4	1	3,512	428	3,940	546	34	3,687	101	3,788	430	38	7,199	529	7,728	976	72	8,175	601	8,776
		2	8,706	2,170	10,876	1,272	320	2,534	236	2,770	195	24	11,240	2,406	13,646	1,467	344	12,707	2,750	15,457
		3	6,408	2,415	8,823	929	262	1,133	264	1,397	65	8	7,541	2,679	10,220	994	270	8,535	2,949	11,484
		4	3,228	1,676	4,904	353	176	19	4	23	...	...	3,247	1,680	4,927	353	176	3,600	1,856	5,456
		5	1,539	2,670	4,209	55	45	...	...	...	...	...	1,539	2,670	4,209	55	45	1,594	2,715	4,309
	Total	...	23,393	9,359	32,752	3,155	837	7,373	605	7,978	690	70	30,766	9,964	40,730	3,845	907	34,611	10,871	45,482
Sand	5	1	27	231	258	2	22	44	135	179	4	8	71	366	437	6	30	77	396	473
		2	53	336	389	3	55	36	...	36	...	...	89	336	425	3	55	92	391	483
		3	34	49	83	23	12	...	...	...	...	...	34	49	83	23	12	57	61	118
		4	...	93	93	...	5	...	...	...	..	...	...	93	93	...	5	..	98	98
		5	31	102	133	...	...	...	...	...	...	...	31	102	133	...	...	31	102	133
	Total	...	145	811	956	28	94	80	135	215	4	8	225	946	1,171	32	102	257	1,048	1,305
	Grand Total	...	23,591	10,170	33,761	3,195	931	7,453	740	8,193	694	78	31,044	10,910	41,954	3,889	1,009	34,933	11,919	46,852

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Particulars of soils.	Description of soils.		MADURA.					MELUR.					TOTAL.					GRAND TOTAL.		
			Government.			Inam.		Government.			Inam.		Government.			Inam.		Government and Inam.		
	Class.	Sort.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.	Wet.	Dry.	Wet.	Dry.	Total.
			Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Red Loam	7	1	79	450	529	11	69	4,327	3,821	8,148	187	339	4,406	4,271	8,677	198	408	4,604	4,679	9,283
		2	864	999	1,863	93	203	1,182	2,140	3,322	31	137	2,046	3,139	5,185	124	340	2,170	3,479	5,649
		3	1,294	1,214	2,508	91	148	158	221	379	2	...	1,452	1,435	2,887	93	148	1,545	1,583	3,128
		4	432	1,143	1,575	25	81	188	19	207	4	...	620	1,162	1,782	29	81	649	1,243	1,892
		5	17	196	213	3	4	...	...	...	...	...	17	196	213	3	4	20	200	220
	Total	...	2,686	4,002	6,688	223	505	5,855	6,201	12,056	224	476	8,541	10,203	18,744	447	981	8,988	11,184	20,172
Red Sand	8	1	46	3,399	3,445	1	437	156	6,638	6,794	...	315	202	10,037	10,239	1	752	203	10,789	10,992
		2	40	5,030	5,070	5	357	47	3,244	3,291	...	129	87	8,274	8,361	5	486	92	8,760	8,852
		3	116	5,521	5,637	15	157	24	105	129	...	2	140	5,626	5,766	15	159	155	5,785	5,940
		4	3	1,083	1,086	...	13	...	...	...	...	...	3	1,083	1,086	...	13	3	1,096	1,099
		5	...	13	13	...	...	...	...	...	...	...	...	13	13	...	...	...	13	13
	Total	...	205	15,046	15,251	21	964	227	9,987	10,214	...	446	432	25,033	25,465	21	1,419	453	26,443	26,896
	Grand Total	...	2,891	19,048	21,939	244	1,469	6,082	16,188	22,270	224	922	8,973	35,236	44,209	468	2,391	9,441	37,627	47,068
	Grand Total of Black and Red soils		26,482	29,218	55,700	3,439	2,400	13,535	16,928	30,463	918	1,000	40,017	46,146	86,163	4,357	3,400	44,374	49,546	93,920

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11. GRAIN VALUATION.—I have noticed above that, from the necessary circumstances of the case, it has not been possible in Madura to arrive at a valuation of the various classes of soils by means of very wide-spread experiments. I have taken care, however, that the results of experiments should not be wanting in that portion of the tract which is already irrigated by river channels and small tanks. The season during which the experiments were made was a very unfavorable one, as may be learnt from the Land Revenue Report of the year. The yield in many parts of the channel-irrigated tract was hardly above three-fifths of an average crop, owing to the lateness and general inopportuneness of the river freshes. Under the small rain-fed tanks the yield was, in the great majority of cases, far below the average, and in perhaps one-fourth of the area the crop never came to maturity at all owing to want of rain. The experiments, therefore, must not be taken as a true index of the productive qualities of the fields in which they were made. Even as they are, however, they warrant, I think, great confidence that the land is not generally inferior in quality, and that the art of wet cultivation is fairly understood in the district. I may explain here that the experiments do not show, and were not intended to show, the average yield of the season under the different sources of irrigation where they were made. The sole object in making the experiments having been to test the probable yield of the lands when under good irrigation, very few experiments were made in lands where the supply of water had been so perceptibly insufficient as not to justify any inference that might be drawn from the result of the experiment as to the productiveness of the land under fair irrigation. One thousand and seven experiments have been made in all under anicut channels, koramboo channels, and rain-fed tanks. Those made on lands irrigated by the channels from the Perani anicut across the Vigay are shown in the subjoined statement:—

DESCRIPTION OF SOIL.		GOOD.		MIDDLING.		BAD.		TOTAL.	
Class.	Sort.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.
4	1	82	1,288	56	868	4	563	142	1,104
4	2	25	848	13	608	9	444	47	704
4	3	2	744	3	444	2	320	7	496
7	1	2	1,280	2	884	...	...	4	1,082
TOTAL .		111	1,180	74	808	15	460	200	988

Analysis of Experiments where the Crop is classed as Good.

Outturn per acre.	4·1	4·2	4·3	7·1
Over 1,500 measures	15	...	...	
1,500 to 1,400	10	...	...	1
1,400 to 1,300	6	...	...	...
1,300 to 1,200	17	1	...	...
1,200 to 1,100	21	...	...	...
1,100 to 1,000	13	2	...	1
1,000 to 900	...	3	...	...
900 to 800	...	8	...	...
800 to 700	...	11	2	...
TOTAL . .	82	25	2	2

12. The total area of Government land irrigated by this anicut channel is 3,838 acres. The experiments made number 200, the crop over one-fourth of an acre being, in each experiment, reaped, threshed, and measured on the spot. The average outturn obtained over the total number of experiments is 988 Madras measures per acre. A brief analysis of the results of the experiments where the crop tested was a well-grown one is given at the foot of the statement. It may be seen that in 111 experiments in crops classed as "good," the average yield obtained amounted to 1,180 Madras measures per acre. In 85 of these experiments the

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yield amounted to an average of over 1,280 measures per acre. Due weight should be allowed to these figures. I feel myself quite justified in stating that, under this anicut channel, if a fair supply of water be guaranteed, a less production than 1,000 Madras measures per acre, on an average of years, can only be due to exceedingly careless cultivation; and that a careful cultivator should consider himself unfortunate if he does not usually realise 1,200 to 1,400 Madras measures per acre. I think that it would be a great mistake to under-rate the value of irrigation in this part of the country. I see no reason to doubt that the bulk of the land under the new channels will rival the productiveness of the land under the present anicut channel, while I am of opinion that much of the land in Melur will surpass it. It seems sufficiently evident from the result of these experiments that there is no want of fertilising power in the waters of the Vigay, and as the sources of the Periar are not very distant from those of the former river, it may fairly be hoped that the fertilising power of the waters of the one will not be absent from those of the other.

13. The next statement shows the result of 340 experiments made in wet lands irrigated by channels into which the water of the Vigay is forced by means of koramboos or embankments of sand and brushwood thrown out into the bed of the river. The area of Government lands irrigated by these channels during the past year, Fasli 1285, amounted to 5,249 acres.

Description of soil.		Good.		Middling.		Bad.		Total.	
Class.	Sort.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.
4	1	38	1,196	48	820	19	572	105	912
4	2	63	856	57	588	25	392	145	672
4	3	24	624	14	456	16	304	54	484
4	4	6	614	2	364	8	292	16	420
3	1	1	1,040	...	...	7	532	8	596
3	2	...	...	3	544	...	...	3	544
7	1	...	...	2	740	...	...	2	740
7	3	...	...	...	...	2	316	2	316
7	4	...	...	...	...	3	284	3	284
8	1	...	...	2	570	...	...	2	570
Total		132	900	128	660	80	412	340	696

Analysis of Experiments where the Crop is classed as Good.

Outturn per acre.	4·1	4·2	4·3	4·4	3·1	3·2	7·1	7·3	7·4	8·1
Over 1,500 measures	3	...	...	...	...	...	...	...	...	...
1,500 to 1,400	3	...	...	...	...	...	...	...	...	...
1,400 to 1,300	4		...	...	...	...	...	...	...	...
1,300 to 1,200	5	4	...	...	...	...	...	...	...	...
1,200 to 1,100	10	...	...	...	...	...	...	...	...	...
1,100 to 1,000	13	6	...	...	1	...	...	...	...	...
1,000 to 900	...	8	...	1	...	...	...	...	...	...
900 to 800	...	19	...	...	...	...	...	...	...	...
800 to 700	...	26	2	1	...	...	...	...	...	...
700 to 600	...	...	13	1	...	...	...	...	...	...
600 to 500	...	...	9	...	...	...	...	...	...	...
500 to 400	...	...	...	3	...	...	...	...	...	...
Total	38	63	24	6	1	...	...	...	...	...

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14. The result of these experiments is not at first sight so assuring as that of the experiments made under the anicut channels. The average yield of 132 good crops tested was 900 Madras measures per acre, that on 128 inferior crops 660 Madras measures per acre, while on 80 bad crops the average yield was only 412 measures. The low outturn on these lands is due to a great extent, as in the former series of experiments, to the lateness and general inopportuneness of the floods in the Vigay; but the main cause of their great inferiority to the anicut-irrigated lands, than which, however, they pay a higher assessment, is the want of proper drainage. The lands are on a low level, and there is no good flow of water to carry off the deleterious salts which are very prevalent in this part of the Madura taluq, and which, when the land is under irrigation, always rise to the surface of the soil. The necessity for providing for a thorough drainage for the lands to be newly irrigated is a question of the first importance, and must receive the most careful attention of the Engineers. The difference between good and bad drainage is the difference between an average crop of 500 measures or considerably less, and one of 1,000 measures or considerably more. With good drainage and a good flow of water in the Periar channels, which latter may easily be secured, I see nothing in the results of the experiments just remarked on to lead me to qualify my statements in the previous paragraphs as to the probable productiveness of the lands to be newly irrigated.

15. The third and last series of experiments which I have to review are those which were made under the small rain-fed tanks in the tract which is to be brought under the influence of the project. The extremely unfavorable nature of the season has rendered the utility of these experiments much less than it might have been, for, as I have said above, what is needed is evidence of the fertility of the land under a plentiful supply of water such as the Periar channels will afford. Making due allowance, however, for the nature of the season, the results of even these experiments are not on the whole unfavorable. They are shown in the subjoined statement. In the Madura taluq, to which taluq circumstances confined the experiments, the area of Govenment land under these rain-fed tanks was, in Fasli 1285, about 12,918 acres :—

Description of soil.		Good.		Middling.		Bad.		Total.	
Class.	Sort.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.	Number of Kyles.	Average outturn per acre.
4	1	12	1,200	6	868	1	608	19	1,064
4	2	69	900	39	604	53	344	161	652
4	3	79	700	38	464	68	296	185	500
4	4	36	576	8	376	15	260	59	468
4	5	1	360	...	...	2	290	3	312
7	2	2	920	1	528	...	...	3	788
7	3	10	796	6	436	15	276	31	476
7	4	...	...	1	376	3	208	4	250
8	1	...	...	...	...	1	240	1	240
8	3	...	...	...	...	1	340	1	340
	...								
	Total	209	780	99	536	159	304	467	564

Analysis of Experiments where the Crop is classed as good.

Outturn per acre.	4·1	4·2	4·3	4·4	4·5	7·2	7·3	7·4	8·1	8·3
1,500 to 1,400	1	...	2	...	...	...	...	...	...	...
1,400 to 1,300	...	...	1	...	...	...	...	...	...	...
1,300 to 1,200	4	1	2	...	...	...	...	...	...	...
1,200 to 1,100	6	7	1	...	...	...	...	...	...	...
1,100 to 1,000	1	16	...	...	...	...	1	...	...	...
1,000 to 900	...	7	7	...	...	1	2	...	...	...
900 to 800	...	21	2	1	...	1	2	...	...	...
800 to 700	...	15	14	3	...	...	2	...	...	...
700 to 600	...	2	18	9	...	...	2	...	...	...
600 to 500	...	...	32	14	...	...	1	...	...	...
500 to 400	...	...	...	9	...	...	...	...	...	...
400 to 300	...	...	...	..	1	...	...	...	...	...
Total	12	69	79	36	1	2	10	...	...	...

On the total number of 467 experiments, the average yield shown is 564 Madras measures per acre, 209 of the experiments gave an average yield of 780 Madras measures per acre, while 60 of this latter number gave an average of upwards of 900 Madras measures per acre. It is

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clear that, if, in so bad a season as was that just passed in Madura, so fair an outturn is obtainable under rain-fed tanks, there is every hope that the land under favorable irrigation will give a yield very largely increased. Taking into consideration the results of the three series of experiments which have been noticed above, I am satisfied that the grain valuation proposed below for the different classes of soil is a very reasonable one, and that it does not err on the side of strictness. The valuation in Column 4, it should be stated, is that for a good crop in a favorable season; but, as is the custom in all new settlements, a deduction is made from this valuation to meet vicissitudes of season. This deduction I have taken as usual at one-fifth of the full crop, and the net valuation on which the assessment is calculated, after deducting cost of cultivation, is that shown in Column 6.

Description of soil.	Class.	Sort.	Grain valuation.	Deduct 20 per cent. for vicissitudes of season and for inclusion of poram-bokes.	Remainder actual grain valuation.
			Measures.	Measures.	Measures.
Black clay	3	1	1,000	200	800
		2	900	180	720
		3	800	160	640
		4	620	124	496
		5	620	124	496
Black loam	4	1	1,000	200	800
		2	900	180	720
		3	800	160	640
		4	620	124	496
		5	620	124	496
Black sand	5	1	900	180	720
		2	800	160	640
		3	700	140	560
		4	620	124	496
		5	620	124	496
Red loam	7	1	1,000	200	800
		2	900	180	720
		3	800	160	640
		4	620	124	496
		5	620	124	496
Red sand	8	1	900	180	720
		2	800	160	640
		3	700	140	560
		4	620	124	496
		5	620	124	496

16. The average grain valuation per acre in the tract classified for an average year amounts to 672 Madras measures.* Compared below with the average yields obtained by experiments under the different sources of irrigation already existing in the tract, and with those obtained under the Bowani and Noel river channels in Coimbatore, the valuation will, I think, appear a reasonable one:—

District.	Source of irrigation.	Group.	Description of paddy.	Number of experiments.	Average outturn per acre.
1	2	3	4	5	6
					M. M.
Coimbatore	Bowani channels	1	Shemba	701	1,177
	Bowani channels	1	Kar	524	1,046
	Bowani channels	2	Kar	150	1,315
	Noel river channels	2	Shemba	198	1,089
Madura	Anicut channels of Vigay river	—	Shemba	200	988
	Koramboo channels	...	Shemba	340	696
	Rain-fed tanks	...	Shemba	467	564
	TOTAL	—	...	2,580	—

* The average grain valuation here shown, it should be stated, is that of the whole tract classified. Excluding the poorer lands which will probably not be brought under irrigation, and including the lands now in the beds of tanks but hereafter to be brought under cultivation, the average grain value of the ryotwari lands to be irrigated will be about 700 Madras measures per acre. The poorer lands alluded to are of so very inferior a quality, that the lowest rate of assessment proposed will be sufficiently high in all probability to keep them out of cultivation. It would be useless to class these lands as dry lands, for dry crops would not grow on them.

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17. It may appear, at first sight, from an inspection of the tables of experiments which I have given, that I have not assessed the better class of lands sufficiently high, and have assessed the inferior sorts at rates higher than the experiments seem to warrant; but this is hardly a justifiable inference, at any rate, as regards the poorer soils; for though at present the difference in the yields of the higher and lower sorts is very considerable, it is so, for the most part, on account of a deficiency of water to the latter—a deficiency which will not exist when the project is carried out. The improvement of the poorer sorts will be greater in proportion than that on the higher sorts, and the outturn on them will, in all probability, very considerably exceed the valuation. It is fairer at present to take average results, as I have done above, in estimating the grain valuation, than to value each sort at the rate obtained by experiments made in it—a course which would be out of the question for reasons I have already stated. In Coimbatore, where the averages obtained, it will be seen, are very high, a crop yielding less than 700 Madras measures per acre was quite the exception, though the experiments were made in all directions and on all classes of land.

NOTE.

Since submitting my report on the Periar Project, I have learnt that Colonel Brownlow, R.E., Inspector-General of Irrigation, objects to the method therein proposed of passing the water of the river round the flank of the dam during construction, and considers that the culverts provided for that purpose would be a source of risk.

2. This method was proposed after careful consideration of every possible alternative (including that about to be discussed in this note), and I am convinced that no risk whatever is to be apprehended from its adoption, and that no other plan combines in the same degree the required elements of security, efficiency and economy.

3. It gives, what no other practicable scheme does, the power of absolute control over the water-levels during the construction of the work (except during quite abnormal floods), and that of emptying the lake after completion, or of discharging a portion of its contents into the river below, a power which, under certain circumstances, may be of great value.

4. In case, however, Colonel Brownlow's objection should be insuperable, the best alternative remains to be considered.

5. The simplest and cheapest is simply to allow the water to go freely over the dam, but I do not recommend its adoption; the perpetual trouble of setting up frames in water, the annoyance to the workmen of moving about in it, and, above all, the impossibility of testing leakage where water is constantly running down the rear slope, are all evils for avoiding which a considerable expense may well be incurred.

6. It is true that many dams have been constructed in this manner, but they were all over streams which were either dry for part of the year, or which were mere rivulets in comparison with the Periar, and I do not know of any case in which the water of a considerable stream has been allowed to pass during construction over a dam of any height.

7. If the ordinary stream cannot be passed by a culvert under the dam, it must be passed by a siphon above it, and the question is what the dimensions of the siphon should be. No arrangement can be considered satisfactory in which the passing of water over the substance of the dam is an ordinary as distinguished from an exceptional occurrence.

8. The scheme submitted by me provides for passing the whole stream under the dam except during about eight or ten days of the whole period (900 working days) occupied in its construction, but it is not necessary to keep to so a small number as this, if doing so involve any considerable expense.

9. I consider that, in order to ensure safety, thorough inspection, and careful workmanship, it is necessary that the siphon should be able to pass the whole discharge of the stream during at least five days out of six; and, in order to do this, there being but little margin between the water-level and the top of the work, the records show that the discharging power must be about 1,800 cubic feet per second, the maximum effective head being 25 feet.

10. A single pipe with an area of 72 square feet or a diameter of 9·58 feet would provide for this; but as it is necessary to make separate provision for the supply of water to the driving machinery, two pipes must be provided.

11. In order to get during the early part of the work (when it is most wanted) the full effect of the atmospheric pressure, the temporary dam must be made 35 feet high instead of 30 feet as originally proposed.

12. The arrangements recommended are shewn on drawing No. 10-A, and their cost in the Estimates Nos. 3-A and 6-A submitted herewith. There is a pipe on the left bank, 8·91 feet in diameter, and one on the right for the supply of the driving machinery, 6·32 feet in diameter.

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13. The effective head in a siphon is the difference between the water surfaces above and below, or 33 feet *minus* the maximum height of the diameter of the pipe above the upper surface, whichever may be the least.

14. In this case the latter is 26 feet, but during the early part of the work the former is on the left bank 25 feet, as the water will be headed up in the discharge cutting to about 10 feet, and on the right bank 8 feet, as the weir which regulates the level in the penstock cutting is at 25 feet, and there will be about 2 feet, going over this when the water above is up to the crest of the temporary dam.

15. The areas of the pipes are 62·36 and 31·82 square feet respectively, and if the velocity in feet per second be taken at $4\frac{1}{2}$ times the square root of the head, the discharges will be 1,403 and 540 cubic feet per second, rather more than the required amount.

16. The discharging power of the right bank pipe will increase as the main dam rises, until the latter reaches 50 feet, when the full head of 25 feet will be available for both pipes, and the total discharge will be 2,119 cubic feet per second.

17. The pipes will be made of $\frac{1}{8}$-inch iron sheets with double rivetted but joints. The diameters are those corresponding to circumferences of 7 and 5 sheets of 4 feet each, which is the greatest breadth usually made. The materials will be sent out ready prepared, and put together *in situ*; ample allowance is made in the estimate for the cost of erection.

18. The maximum pressure, either internal or external, to which the pipes can be subjected, is that of about 25 feet of water or, say, 11 pounds on the square inch, so that the greatest strain on the material is $8 \times 11 \times 8{\cdot}91 \times 6 = 4{,}704$ lb. on the square inch for the left bank pipe, and $8 \times 11 \times 6{\cdot}36 \times 6 = 3{,}375$ lb. on the square inch for the right bank, which is very moderate for good double rivetted joints.

19. When the discharge of the river is low, the water-level above the temporary dam would fall below the 25 feet necessary for the supply of the turbines, as for instance in February, when it averages only 352 cubic feet per second, and the level would fall to about 11 feet. To prevent this a cover is provided at 4 feet from the upper mouth of the pipe of a diameter slightly larger than the latter and fixed to it by iron bars. A valve consisting of a length of plain pipe 4 feet long and just large enough to slide easily over the main pipe is attached to floats by chains of such a length that, when the water sinks to near the desired minimum level, the valve descends and closes the space between the covering plate and the main pipe, thereby shutting off the water from the latter. This valve is obviously in equilibrium throughout, and may be made to slide quite loosely over the main pipe, as there is no necessity for anything like an absolute closure of the latter.

20. In order to prevent the entrance of air at the discharging mouth of the siphon, the latter is surrounded by a tank whose diameter is about one and-a-half that of the main pipe, and its upper rim 6 inches above the mouth of the latter; this is a simpler and cheaper arrangement than turning up the pipes at their mouths. These tanks are not necessary during the early part of the work, when both siphons will discharge into water standing above the level of their mouths.

21. It will be seen from the plan that the left bank siphon rests on the ground at 35 feet above the river-bed, and communicates with the latter by cuttings. Until the main dam reaches this level, the work can proceed without interruption, and no moving of the siphon is required. After the 35 feet level the latter has to be moved from time to time, as the space under it has to be filled in, and this will be done in the following manner.

22. The pipe being emptied will be raised by the trestles shown on the drawings to a height sufficient to allow of the completion of the work under it, the water-supply of the river (over and above what the other siphon can take) being absorbed by the margin between the water-level and the crest of the work.

23. This margin varies in depth, under normal circumstances, from 10 to 15 feet, and in content from 150 millions to 4,000 millions of cubic feet. The total time occupied in raising, completing the work below, lowering and filling the pipe again is calculated at ten hours as a maximum—a period for which the minimum margin of 150 millions of cubic feet would absorb a discharge of 4,200 cubic feet per second. Of course, if the river was in high fresh at the time, the available margin would be reduced, and the risk of submersion increased; but this is a risk which must be faced so far as it cannot be avoided by judicious timing of the various operations.

24. To allow of the easy raising and lowering of the pipes, they are attached to counterbalances, composed of blocks of concrete of weight slightly less than their own. To each counterbalance is fixed a small water tank, which, when filled, causes the counterbalance to descend, and when emptied causes it to rise.

25. The tanks will be filled at leisure when the siphon is at work, and when the latter is

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emptied it will rise at once; the work below being completed, the water will be allowed to run out of the tanks and the pipe will descend into position again.

26. The siphon will be raised and lowered in one vertical plane until its lower limb is clear of the ground-level, after which it will be moved longitudinally up the bank from time to time so as to keep this lower limb just clear of the ground, and reduce as much as possible the height of the trestles which will be necessary to support the rear portion of the pipe as the thickness of the dam diminishes.

27. The right bank siphon does not require to be removed until the work reaches the 45 feet-level, and here the conditions are somewhat different from those on the left bank. The supply of power to the whole of the machinery depends upon this pipe, and consequently it cannot be raised during working hours; that is to say, that the space underneath its original position cannot be filled in until it is lowered again, and it cannot therefore be raised and lowered in one vertical plane, but must have a certain amount of longitudinal traverse. This is provided for by the return cuttings shown on the plan which allows the pipe to be traversed to any position between the limits c d and e f. Of course, when once the lower limb is clear of the ground, this pipe, like the other, will be moved longitudinally up the bank.

28. It is necessary that the pipes should be emptied before being moved, because their weight, when full, would be too great to be conveniently dealt with, even if horizontal traversing only were to be adopted (as would be possible, though the arrangements would be far less convenient than those proposed); and the following arrangements are provided to allow of this being easily and rapidly done.

29. A small cock is fixed in the highest part of the main pipe, by the opening of which cock air is admitted to the pipe, and the water at once driven out.

30. Alongside of the main pipe runs an ordinary cast-iron pipe 6 inches in diameter; this pipe is never emptied (the weight of water contained in it being trifling), being furnished with a stop-cock at each end, which is closed before the pipe leaves the water on lifting.

31. The object of this tube is twofold: first, to provide a convenient source of power (by means of a small turbine fixed in its length) for working the air pump, by which the main pipe has to be exhausted; and, second, to supply water to the tank at the lower end of the latter during the process of exhaustion.

32. This latter is required, because without it it would be necessary to provide an air-tight valve for closing the lower mouth of the siphon during the process, and the cost of this valve and the apparatus for opening and closing it would probably exceed that of the small pipe and its appurtenances, and be far less practically convenient. Indeed, I have failed in designing any arrangement of this kind which I consider thoroughly satisfactory.

33. The siphon having been lowered empty into position, the air pump will be set up in a position where it can be conveniently worked by a strap from the small turbine and connected by a flexible pipe to the cock in the main pipe, the air from which will be thoroughly exhausted.

34. It has been said that the small pipe is never intended to be emptied; but if by any accident the water should be allowed to run out, it can be re-filled by the air pump in a few minutes, a cock similar to that on the main pipe being provided for the purpose.

35. The small turbines cost but little, and it will be a great convenience to have a source of power which can be immediately and rapidly applied to the working of the air pump. Indeed, it will probably be often found convenient to have on the work itself a source from which power may be taken for pumping, working a hoist, or other contingent work.

36. The turbine will supply from three to six horse-power, according to the water-levels; the smaller of these powers will suffice to exhaust at the rate of 60 cubic feet per minute, so that the exhaustion of the larger pipe will take about 3½ hours, and of the smaller about half that time.

37. The estimates have been made on liberal terms, for the rates of R350 per ton material and R200 per ton for workmanship are certainly in excess of what will be found actually necessary.

38. It will be seen that the actual cost is R51,000 against R39,000 provided in the estimates for the culverts; the difference of R12,000 is so small in comparison with the total of the estimate, that it does not seem necessary to alter the Financial Statements.

39. Three alternative arrangements have been considered, but it is unnecessary to discuss them here, as they are all clearly inferior to that now proposed.

40. There is, however, an alternative mode of constructing the pipes, which I think is worthy of consideration, that is, to make them of wooden planks, say 2 inches thick, bound round with iron or steel wire or wire rope. The timber at R3 per cubic foot would cost R14 and R10 per running foot for the two sizes of pipes, and the binding R15 and R9 respectively, to which might be added R5 and R3 for painting, tarring, and caulking,

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making the total cost R32 and 22 per foot against R44 and 31, which is the estimated cost of the iron pipes. I see no reason why wooden pipes should not be made perfectly water-tight under such small pressures as we are dealing with, and they would be more easy to make up and keep in repair than the iron ones.

CHEPAUK,
31st March 1883. (Signed) J. PENNYCUICK, *Major, R.E.*

Note by Colonel J. O. HASTED, *R.E., Acting Chief Engineer for Irrigation, dated 11th April 1883.*

In G. O., No. 1164 W., 8th May 1882, Major J. Pennycuick, R.E., was appointed to revise the designs and estimates for the Periar Project, and with the above letters that officer has submitted his report with complete estimates. These estimates have since been discussed, and Major Pennycuick has forwarded the notes above referred to in consequence, with alternative estimates for part of the works. The forecast statements have received the approval of the Revenue authorities, and have been revised in accordance with the latest instructions, and the estimates are therefore now submitted in a complete form to be forwarded to the Government of India.

2. In his report, paragraphs 9 to 28, Major Pennycuick has given "a history of the Present Project," which explains all that has been done in past years. It is sufficient here to say that the project, as now submitted, agrees generally with that submitted in 1872 after careful and prolonged investigations by Mr. R. Smith, and approved by Colonel Oakes and Colonel Mullins, with the exception that the dam which it was originally proposed to construct of earth by the silting process is now intended to be constructed of concrete throughout. The main features of the projects are the same, a dam across the Periar on the Travancore side of the Western Ghâts, a tunnel through the watershed ridge, a series of regulating sluices for passing the water diverted from Travancore into the Madura District round the anicuts on the Sooroolly river, and distributary works; the two last-named having been very carefully worked out originally, have not now been revised, but the estimates for the dam and head works have, after a careful study of the subject for years, been most thoroughly worked out by Major Pennycuick.

3. The supply is derived from the Periar draining 300 square miles of the Western Ghâts, and is beyond question. Tables VII and VIII attached to the report give an estimate of the amount of water available, which, not taking into account rainfall on the tract to be irrigated, shows an ample supply for 150,000 acres. It has been suggested that to fill the dry bed of a river in the eastern plains will require a vast quantity of water, but it must be remembered that when the works are completed, the bed of the river will never be altogether dry, and it will be observed that to fill it up after each hot season 500 millions of cubic feet have been allowed.

4. The land commanded by the channels is about 200,000 acres, of which it is proposed to irrigate 101,000, with first crop and 35,343 acres second crop. An elaborate report on the subject of revenue to be expected was made* by Mr. Clogstoun, then Deputy Director of Revenue Settlement, now Accountant General, on which the forecast of revenue has been based, and which has received the approval of the present Collector. Attached to the forecast statements is a note explaining briefly how the figures are obtained.

* (Public Works Department) G. O., No. 115, 10th March 1877.

5. The original project was to cost R53,99,700 direct charges without any payment to the Travancore Government for the use of the water, and the estimated return was R6,24,600. The estimates now submitted are as follows:—

Direct Charges.

	R
Works	52,00,000
Establishment	9,25,000
Tools and plant	60,000
	61,85,000
Indirect charges	2,56,463
	64,41,463

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The works are expected to be completed in six years, and the irrigation fully developed in ten years after their completion. The gross revenue will then be ₹7,00,000, the working expenses and collection charges ₹1,25,400, and the net revenue will therefore be—

	₹
Including enhanced land revenue . .	5,74,600, or 9·29 per cent. on direct charges.
Excluding „ „ „ . .	5,31,912, or 8·92 on direct and indirect charges.

Under works a sum of eight lakhs is allowed as compensation to the Travancore Government. The subject is not yet settled, but negotiations are so far advanced that it seems certain this provision will be more than sufficient. The latest offer* made to the Travancore Government is six lakhs of rupees, the cession of certain small tracts of country, and ₹50 per acre for every acre occupied above 8,000.

* G. O. No. 238 (Political), 21st March 1883.

6. The works estimated for are so peculiar in character, and, being situated as they are in an almost uninhabited jungle on hills which are for a part of the year very unhealthy, require a method of construction so unusual, that it is necessary here to make some remarks on the designs submitted.

The dam, which is 155′ in height above the deep bed of the river with a parapet of 5′, the level of the escape weirs being 144′ and the probable actual maximum water-level being 153·16, is intended to be made entirely of concrete. The large dams which have been constructed in the south of France, with which the proposed dam may be compared, were made of rubble masonry, and there are no examples of any large concrete dam, but it is considered that concrete will prove in all respects a more suitable material than rubble masonry. Made of good materials, the rock on the spot and hydraulic mortar, and well rammed, it will bear the same crushing weight, and will be perfectly solid, and the construction will be simpler.

7. As regards the section of the dam, Major Pennycuick has submitted a note, which is attached to his report, in which he enters very fully into the calculations on which it is designed. In this note he gives his reasons for differing from the "old method" of calculating pressures, and also from the French authority, M. Bouvier, who has lately investigated the subject, and prepared designs for dams of about the same size. The subject is one which requires special study, and it is suggested that Mr. Molesworth, whom we have for years looked to as the highest authority on the subject, should be invited to discuss Major Pennycuick's note before the section is definitely decided on. Major Pennycuick's calculations are believed to be sound, and his section to be perfectly safe; but as he has propounded a new theory, it is advisable that his calculations should be discussed by known experts. On the proposed section, which is submitted, the line of rear slope as calculated by M. Bouvier's method is also shown. M. Bouvier's calculations would require somewhat more material, but the excess is so small that the estimate will in all probability suffice whatever section is determined on.

8. The escape dam is designed on the same principles as the main dam, and the arrangements for the water cushion are considered satisfactory. There will be two escapes with an aggregate length of 920′, and their effect in an extraordinary flood is shown in Table IV attached to the report.

9. There has been some discussion, since the report was written, on the subject of the escape culverts proposed by Major Pennycuick. He proposed two culverts, one on either bank of the river, to dispose of the water during the construction of the dam; that on the right bank supplying the turbine, which is to drive the manufacturing machinery. These culverts were to be closed by an equilibrium self-acting shutter very ingeniously contrived, but it was considered that in a work of these dimensions any under passage would be objectionable, and doubtful whether any self-acting machinery, such as that proposed, would prove satisfactory. Major Pennycuick has therefore designed an alternative arrangement whereby the flood-water, except in high floods, may be passed over the dam by means of siphons, one of which will feed the turbine. These designs have been very carefully worked out, and it has been considered whether the siphon tubes, instead of passing over the dam itself, could not be laid on the slope of the bank on either side; the difficulty of raising them in this position has been considered a sufficient obstacle to such an arrangement, and the proposed arrangement, which is no doubt feasible, seems the most satisfactory. The cost of the siphons would be only ₹12,000 more than of the escape culverts, and it has not therefore been considered necessary to alter the forecast statements. It would, of course, be possible to allow all surplus to pass freely over the dam during construction, but this, though it might safely be done, would be a hindrance to the work, and in any case it is advisable to have a siphon to supply the turbine, as it must evidently be economical to utilize the water-power available. The only question seems to be whether smaller discharging power might not be sufficient, more flood-water being allowed to pass over

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the dam and less expensive siphons being provided. It has not, however, been considered advisable to reduce the amount of the estimate.

10. The equilibrium sluice proposed to be constructed at the entrance to the tunnel, by which the supply to Madura is to be regulated, is open to some of the objections raised to those proposed for the escape culverts. The principle on which the sluice is constructed is substantially the same as that on which equilibrium valve sluices were proposed by Mr. F. Stoney, two of which were purchased by the Madras Government. In Mr. Stoney's sluice the water was admitted to both sides of the shutter; in Major Pennycuick's it is admitted within the shutter and presses outwards on both faces, so that in both cases there is no pressure due to the head of water to deal with. The principle is believed to be correct. Major Pennycuick has further introduced in the shutters hollow water-tight cylinders of such size that the weight of the shutter becomes of little account, and the power required to lift it is very small. It is proposed that the shutters should, by an ingenious arrangement, be raised by buoys floating on the surface of the water in rear, and should thus be self-regulating. It is to this arrangement that exception is taken. The regulating gear is subject to rust, and at the mercy of such things as logs of wood which might be sucked through the sluice. It is thought that it will be found necessary to raise the shutter by means of a screw or by chains, and it is recommended that this point should be considered in carrying out the works. It will probably be necessary also to provide grooves into which shutters could be inserted in case of its being necessary to raise the shutters for the purpose of repairing it at a time when water was not required, or could not be passed through the tunnel. The provision made in the estimate will allow for the necessary alterations in these particulars being attended to.

11. In carrying out the works, machinery has been provided for, the details of which have been very carefully worked by Major Pennycuick, and are shown in the drawings. In this situation there is no doubt but that it will be economical to employ machinery to a great extent, labour being expensive, though in some cases, as for instance in ramming the concrete in the dam, it may prove, should labour be attracted to the work, better to ram by hand. The mortar-mixers and concrete-mixers should certainly be worked by machinery, but the particular form of machine to be used may be left to be decided when the work is commenced. Improvements in machinery are being made so constantly that machines, now considered the best type, may, in a year or two, be superseded. The drills for rock-boring are no exception to this rule. The rates entered in the estimates based on careful inquiry, in some cases in communication with manufacturers, and providing amply for carriage, will suffice. The arrangements proposed for working the machinery may be accepted subject to such alterations as further experience may show to be necessary. The wire tramway up the ghât and the traction engines above and below are also approved. Should it be decided that the works are to be commenced at once, it is recommended that Major Pennycuick, who is now proceeding to England on furlough, should be entrusted with the duty of selecting the machinery required within the sums allotted. That officer's long acquaintance with the project and assiduous study of the details of the works point to him as the best selection that can be made for starting the work.

12. The rates to be allowed for work have been the subject of careful inquiry. When the original project was prepared, this subject received the attention of Mr. R. Smith, Major Pennycuick and Colonel Mullins, and it was the opinion of the latter officer that the rates proposed were too low. The use of machinery will have a considerable effect on the rates; and the opening out of the workshop will make it easier to obtain labour than it hitherto has been, but the rates as now worked out are in excess of those originally allowed, and it is believed will prove ample. The principal item in the work is concrete, and this is now estimated at ₹20 per 100 cubic feet, the prevailing rates in the Madura district being ₹15 to ₹17. The data for rates of work are given in an appendix to the report.

13. It has been stated that the works as proposed in the Madura district are as originally estimated after having been most carefully worked out by Mr. R. Smith. After much consideration it was decided that the water now thrown into the Sooroolly and Vigay should be passed round the existing anicuts and not over them. It is to be noticed that all these anicuts supply Government land exclusively, and that therefore there is no reason to anticipate difficulty from interference with the existing supply. The additional water sent down the river will of course benefit existing cultivation; but as the anicuts supply but a very few tanks and the surplus all falls back into the river, there can be but little waste of the water. The designs of some of the works may need modification to some extent, but generally they are approved and may be accepted.

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NOTE.

The ultimate area of irrigation and the estimate of revenue have been arrived at as follows :—

	Number of Taram.	Estimated Yield per Acre, Madras Measures.	Irrigable Area, Acres.	Rate per Acre.	Revenue.
				R	R
Government land	1	1,000	16,431	8½	1,39,663½
Do. do.	2	900	29,522	7½	2,21,415
Do. do.	3	800	21,905	6½	1,42,382½
Do. do.	4	700	5,849	5½	32,169½
Do. do.	5	620	2,643	5	13.215
Total	...	...	76,350	...	5,48,845½
Tank beds	...	...	9,196	8	73,568
Usual wet inams	...	...	4,356	Free.	...
Inams, dry	...	...	3,400	6	20,400
Zemindari and inam land	...	...	15,216	6	91,260
Total	...	...	108,512	...	7,34,073½
Deduct revenue due to old irrigation, average of ten years' collections	...	...	...	...	1,52,598
Net Total	...	...	...	...	5,81,475½
Deduct area and revenue of land irrigated by Korambors, which it is not advantageous to bring under the project	...	...	7,538	...	22,849½
Net total	...	...	101,074	...	5,58,626
or, say	...	...	101,000	...	...
Second crop	...	...	...	...	1,41,374
Total	...	...	101,000	...	7,00,000

The above estimate is based on Mr. Clogstoun's report printed with G. O., Revenue Department, No. 730 of 17th February 1877, except that, in the case of second-crop cultivation, the assessment has been reduced from R2,15,648 to R1,41,374. The Collector of the Madura District has approved the estimate of revenue, and has countersigned the forecast statement as prepared by Major Pennycuick.

Mr. Clogstoun's report shows that the irrigable area of first crop is 96,088 acres, which includes only 1,000 acres under the first group instead of 5,886 acres, as pointed out in paragraph 33 of his letter, he having assumed that the water required for 5,886 acres of old cultivation would be the same as that required for 1,000 acres of new cultivation. The ultimate area of irrigation is therefore 101,000 acres. The amount of direct and indirect revenue have not been separately estimated, as the rates of assessment proposed are consolidated. The consolidated assessment has been separated into land and irrigation revenue, the former being calculated at the average rate of dry land assessment according to Rule IV, paragraph 7 of G. O., Revenue Department, No. 769 of 5th July 1880.

The extent of unoccupied lands which will be brought under irrigation is 35,998 acres as shown below :—

Dry lands	20,616
Wet do.	6,186
Tank beds	9,196
	35,998

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The share of enhanced land revenue is R46,122 at R1-4-6, the average rate of dry assessment per acre, or say R46,000. The irrigation or direct revenue will then be R6,64,000.

The question whether the irrigation revenue should be levied on zemindari and inam lands at R6 or R4 an acre was raised in paragraph 10 of the letter from the Director of Revenue Settlement, printed with Revenue Department G. O. No. 730 of 17th February 1877. This question has not yet been settled; but if the reduced rate be decided on, the probable reduction in the estimate of revenue may be made good by the probable increase in the extent of second crop, which has been reduced. The net revenue is R5,74,600, which would represent 8·92 per cent. on the proposed capital outlay including indirect charges.

At the end of ten years after the completion of the works, there will be a surplus revenue of R5,92,000 over the interest charges, including interest during construction.

J. O. HASTED, *Colonel, R. E.,*
Acting Chief Engineer for Irrigation.

PERIAR PROJECT.

No. I.

Summary of the Estimated Direct Charges to Capital Account.

Year.	Works.	Establishment.	Tools and Plant.	Total.	Remarks.
1	2	3	4	5	6
	R	*R*	*R*	*R*	
First	4,00,000	50,000	5,000	4,55,000	
Second	8,00,000	1,75,000	11,000	9,86,000	
Third	8,00,000	1,75,000	11,000	9,86,000	
Fourth	8,00,000	1,75,000	11,000	9,86,000	
Fifth	8,00,000	1,75,000	11,000	9,86,000	
Sixth	8,00,000	7,75,000	11,000	9,86,000	
Seventh	4,00,000	...	...	4,00,000	
Eighth	4,00,000	...	...	4,00,000	
Total	52,00,000	9,25,000	60,000	61,85,000	

No. II.

Summary of the Estimated Indirect Charges to Capital Account (excluding Interest).

Year.	Capitalization of Land Revenue abated.	Loss by Exchange on Payments in England.	Leave and Pension Allowances.	Total.	Remarks.
1	2	3	4	5	6
	R	*R*	*R*	*R*	
First	...	30,000	6,050	36,050	
Second	17,000	2,000	25,000	44,000	
Third	17,000	2,000	25,000	44,000	
Fourth	17,000	2,000	25,000	44,000	
Fifth	17,000	2,000	25,000	44,000	
Sixth	17,413	2,000	25,000	44,413	
Seventh	...	...	...	...	
Eighth	...	...	...	...	
Total	85,413	40,000	1,31,050	2,56,463	

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No. III.

Summary of Growth of Irrigation and Revenue Receipts and Charges.

Year.	Irrigated Area at end of Year.	Revenue Receipts and Charges.						Remarks.
		Gross Revenue due to Works.			Charges, both Direct and Indirect.	Net Revenue due to Works.		
		Direct Receipts.	Enhanced Land Revenue or Indirect Receipts.	Total.		Including enhanced Land Revenue.	Excluding enhanced Land Revenue and Collection Charges thereon at 7·2 per cent.	
1	2	3	4	5	6	7	8	9
	Acres.	₹	₹	₹	₹	₹	₹	
Seventh . . .	11,000	65,400	4,600	70,000	20,040	49,960	45,691	
Eighth . . .	21,000	1,30,800	9,200	1,40,000	40,080	99,920	91,382	
Ninth . . .	31,000	1,96,200	13,800	2,10,000	60,120	1,49,880	1,37,073	
Tenth . . .	41,000	2,61,600	18,400	2,80,000	80,160	1,99,840	1,82,764	
Eleventh . . .	51,000	3,27,000	23,000	3,50,000	1,00,200	2,49,800	2,28,455	
Twelfth . . .	61,000	3,92,400	27,600	4,20,000	1,05,240	3,14,760	2,89,146	
Thirteenth . .	71,000	4,57,800	32,200	4,90,000	1,10,280	3,79,720	3,49 837	
Fourteenth . .	81,000	5,23,200	36,800	5,60,000	1,15,320	4,44,680	4,10,528	
Fifteenth . .	91,000	5,88,600	41,400	6,30,000	1,20,360	5,09,640	4,71,220	
Sixteenth . .	101,000	6,54,000	46,000	7,00,000	1,25,400	5,74,600*	5,31,912	

* 9·29 per cent. on direct charges to capital account.
8·92 per cent. on direct and indirect charges to capital account.

No. IV.

Estimate of Net Financial Results.

Year.	Direct Capital Outlay during the Year.	Direct Capital Outlay to end of Year.	Simple Interest at 4 per cent. on Capital Outlay to end of previous Year *plus* Half Outlay during Years.	Net Revenue including Enhanced Land Revenue, Column 7 of Table III.	Simple Interest less Net Revenue.	Net Revenue less Simple Interest.	Remarks.
1	2	3	4	5	6	7	8
	₹	₹	₹	₹	₹	₹	
First . . .	4,55,000	4,55,000	9,100	.....	9,100	.....	
Second . . .	9,86,000	14,41,000	37,920	.....	37,920	.....	
Third . . .	9,86,000	24,27,000	77,360	.....	77,360	.....	
Fourth . . .	9,86,000	34,13,000	1,16,800	.....	1,16,800	.....	
Fifth . . .	9,86,000	43,99,000	1,56,240	.....	1,56,240	.....	
Sixth . . .	9,86,000	53,85,000	1,95,680	.....	1,56,240	.....	
Seventh . . .	4,00,000	57,85,000	2,23,400	49,960	1,73,440	.....	
Eighth . . .	4,00,000	61,85,000	2,39,400	99,920	1,39,480	.....	
Ninth . . .	.....	61,85,000	2,47,400	1,49,880	77,520	.....	
Tenth . . .	.....	61,85,000	2,47,400	1,99,840	47,560	.....	
Eleventh . . .	.....	61,85,000	2,47,400	2,49,800	.....	2,400	
Twelfth . . .	.....	61,85,000	2,47,400	3,14,760	.....	67,360	
Thirteenth . .	.....	61,85,000	2,47,400	3,79,720	.....	1,32,320	
Fourteenth . .	.....	61,85,000	2,47,400	4,44,680	.....	2,17,280	
Fifteenth . .	.....	61,85,000	2,47,400	5,09,640	.....	2,62,240	
Sixteenth . . .	.....	61,85,000	2,47,400	5,74,600	.....	3,27,200	
Seventeenth . .	.....	61,85,000	2,47,400	5,74,600	.....	3,27,200	
Eighteenth . .	.....	61,85,000	2,47,400	5,74,600	.....	3,27,200	
Total .	.....	.....	35,29,900	41,22,000	10,51,100	16,43,100	
Net Revenue . .	.....	.....	.....	.....	.....	5,92,000	

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APPENDIX TO TABLE No. III.

Statement showing the Estimated Charges on Revenue Account in the Public Works and Civil Departments.

YEAR.	Maintenance Charges in the Public Works Department.	Collection Charges in the Civil Department at 7·2 per cent. on Revenue.	TOTAL.
	R	*R*	*R*
Seventh	15,000	5,040	20,040
Eighth	30,000	10,080	40,080
Ninth	45,000	15,120	60,120
Tenth	60,000	20,160	80,160
Eleventh	75,000	25,200	1,00,200
Twelfth	75,000	30,240	1,05,240
Thirteenth	75,000	35,280	1,10,280
Fourteenth	75,000	40,320	1,15,320
Fifteenth	75,000	45,360	1,20,360
Sixteenth	75,000	50,400	1,25,400

J. O. HASTED, *Colonel, R.E.,*
Acting Chief Engineer for Irrigation.

Note by G. L. MOLESWORTH, ESQ., *C.E., Consulting Engineer to the Government of India for State Railways, on Major Pennycuick's method of calculating the pressures in masonry dams.*

There are two distinct questions in Major Pennycuick's note on the mode of calculation of the pressures in masonry dams, which it is necessary to discuss separately, *viz.*—

1st.—The alleged inaccuracy of M. Bouvier's method.

2nd.—The approximate formulæ which I published some years ago.

To deal with the first of these questions I have thought it desirable to translate from the *Annales des Ponts et Chaussées* the original observations of M. Bouvier on this subject.

These observations are of the highest importance and interest, and I recommend that the translation should be printed and circulated amongst the officers of the Irrigation Department.

Major Pennycuick in his note states that—

"M. Bouvier's method appears to have been accepted by the French Engineers; but its accuracy is open to grave doubts."

On investigating the question, however, I find that the two methods of M. Bouvier and Major Pennycuick respectively do not differ in their results to any appreciable extent, until a certain point is reached near the base of the dam. In fact, for a dam of unlimited height, the results obtained by either method are practically identical; or, as Major Pennycuick observes, so long as this point is above the foot of the front slope, "*it matters very little, except for the principle, which method is employed.*" Even beyond this point, in the case of the Periar dam, the results of the two methods only differ to the extent of ½ per cent. of the total quantity of masonry in the dam, M. Bouvier's results being on the side of safety. The comparative results of the two methods are given in the accompanying drawing No. 1.

There is much uncertainty in the problem of pressure in structures of this character. Professor Rankine, in writing on the subject of masonry dams, remarks—

"The assumption on which the rule is based of an uniform rate of variation of that component of the pressure which is normal to the pressed surface is known to be sensibly correct in the case of beams, and is probably very near the truth in walls of uniform, or nearly uniform, thickness. Whether, or to what extent, it deviates from exactness in walls of varying thickness is uncertain in the present state of our experimental knowledge."

Again M. Bresse, who is considered a high authority in France, remarks (in his *Cours de Méchanique Appliquée*, chapter IX, section 2) :—

"In certain cases there may be different modes of comparing a solid mass of masonry to a prism, and we may be induced to consider several neutral axis. Take, for example, a reservoir dam, which we will, for the

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sake of simplicity, assume to be of the form of a rectangular parallelopiped having two horizontal and four vertical faces.

"This wall, regarded first as a prism, of which the normal sections would be identical with the profile of the wall (*i. e.*, vertical planes perpendicular to the wetted face), will be a solid body loaded transversely and exposed to a bending action. On the other hand, if the horizontal planes be taken for normal section, each section would support an inclined force, the resultant of the pressure of the water, and of the weight of the wall above the plane in question. We might imagine a *crowd of similar examples ! ! (une foule d'exemples semblables)*.

"What, then, is the line which ought to be taken as the neutral axis in order to insure stability?

"This would perhaps be difficult to indicate clearly in a general way, and the perception of the Engineer must often serve as his guide."

In the face of these strong expressions of uncertainty on the part of such eminent authorities, I hesitate to pronounce an authoritative opinion on the points of difference between M. Bouvier and Major Pennycuick. I prefer to leave the question to some mathematician better qualified than myself to decide.

I am inclined, however, to think that M. Bouvier is right for the following reasons:—

M. Bouvier calculates his pressure on an imaginary horizontal plane *mn* (see diagram drawing No. 2), but for facilities of calculation, he takes the projection of this plane on to another plane *mn'* normal to the resultant of pressure.

As he has assumed this projected plane below the horizontal plane *mn*, it becomes necessary to eliminate from the calculations three items, *viz.*—

(*a*) The portion *n' n''* of the plane *n' m*.

(*b*) The weight of the masonry contained in the triangle *nmn'*.

(*c*) The action of the water on the surface *nn'*.

It is necessary to eliminate these, because, being beneath the plane *mn*, they cannot affect it. But if, instead of projecting his imaginary horizontal plane upon an imaginary normal plane *below* it, he had assumed the normal plane *up* to be *above* it, then the mode of reasoning would have been the same, and the results identical in both cases; but as the three items above-mentioned do not enter into the question in the case of the plane *above*, it becomes in this case unnecessary to eliminate anything.

Now one of the eliminated items (the pressure on the surface *n n'* or on a portion of it) plays a considerable part in Major Pennycuick's argument, for he remarks that when this portion, or a part of it, is below the base, it "gives no additional water pressure," consequently there must be a decrease in the maximum pressure on the down-stream face.

If, however, M. Bouvier's formulæ be practically correct for a dam of unlimited height, it is difficult to understand how it can be affected by the variation of conditions which are outside the limit of the formula.

In other words, a formula cannot be vitiated under certain conditions by the omission of an element which does not affect it, and which is not included in it. The water pressure on any portion of the surface *nn'* does not affect the plane *nm*. Consequently the cessation of such pressure, when it falls below the base line, cannot affect it. If the formula be correct for an unlimited height of dam, it would appear to follow as a matter of necessity that it must be so for a limited depth.

If Major Pennycuick be right in his theory, his section will, according to his estimate, effect a saving of ½ per cent. in the masonry. If, on the other hand, he should be wrong, the adoption of his section will add about 25 per cent. to the maximum pressure at a very critical part of the dam; and under the conditions of uncertainty of the whole problem, as indicated by the writings of Rankine and Bresse above quoted, I cannot recommend the Government to risk so serious an increase as 25 per cent. in the pressure for the sake of saving ½ per cent. in the quantity of masonry. Moreover, I find on further investigation that the saving of ½ per cent. supposed to be due to the adoption of Major Pennycuick's section is quite illussory; for Major Pennycuick has omitted from his comparison the relative quantities involved in the form of the up-stream face which more than compensate for the difference involved in the form of the down-stream face (see drawing No. 1); so that, as regards the quantities, the comparison is slightly in favour of M. Bouvier's section.

I am disposed on these grounds to recommend to Government the adoption of Bouvier's section, as shown in drawing No. I, which accompanies this note.

2nd—Approximate Formulæ.

In the year 1866 M.M. Graeff and Delocre published in the *Annales des Ponts et Chaussées* an exhaustive note on the form to be given to high dams of masonry.

The principles laid down in their note were generally accepted, and the dams of Furens, Ban, and Ternay were constructed in accordance with them.

In the year 1873 I had occasion to investigate this subject with the view of ascertaining whether some concise approximate formula might not be devised, which would fulfil the general conditions required with accuracy sufficient for all practical purposes, and which at the

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same time would be capable of ready application for rapid reference, without the necessity for toiling through the numerous and complicated formulæ given by writers on this subject.

After laborious investigation I framed the formulæ—

* y = Ordinate from vertical line to the down-stream face in feet.
s = Ordinate from vertical line to up-stream face.
x = Depth below surface of water in feet.
p = Limit of pressure on masonry in lbs. per square foot.

$$* \; y = 7{\cdot}5 \sqrt{\frac{x^3}{p}}; \quad s = \frac{y}{10}$$

with $y = 0{\cdot}6\, x$ as a minimum.

These formulæ agree very closely with the results obtained by M.M. Graeff and Delocre, but the vertical pressure obtained in their calculations does not represent the *total* pressure, but simply its vertical component; and although I considered this to be of no practical importance in dams under 80 feet in height, yet I thought it necessary to introduce into the formula a sliding factor to allow for this defect in the case of high dams.

The formula with its sliding factor stands as follows:—

$$y = 7{\cdot}5 \sqrt{x^3}$$

and these formulæ were subsequently published in 1874 in the Professional Papers on Indian Engineering.† In publishing the formulæ, I stated that they had "no pretensions to *mathematical* accuracy," and were not intended to supersede the more elaborate treatises on the subject.

† Vol. III, 2nd Series, 1874.

A year afterwards M. Bouvier published in the *Annales des Ponts et Chaussées*‡ observations pointing out the defects in the formulæ of M. M. Graeff and Delocre, and demonstrating that, although their calculations were correct in the case of an empty reservoir, they required considerable modification in the case of the full reservoir.

‡ Vol. X, 5th Series, 1875.

I annex a sheet giving ten different sections of dams worked out on M. Bouvier's method for various conditions of height, limits of pressure, and density of masonry (see drawing No. 3). These sections show that, although M. Bouvier has proceeded entirely on different and independent lines of reasoning from those which I had adopted, yet there is a remarkable coincidence between the results of my formulæ and of his method.

In general my formulæ give a slight excess beyond Bouvier's method at the toe of the dam, whilst Bouvier's method gives a slight excess beyond mine at about one-fourth of the height from the base.

As approximate formulæ, which have no pretensions to mathematical accuracy, I think it will be conceded that my formulæ fulfil very well the conditions for which they were designed.

I say they have no pretensions to *mathematical* accuracy because they do not include the element of the density of the masonry; but this is practically of very little importance, because, when the reservoir is full, the increased pressure due to the greater density of the masonry is almost counterbalanced by the resistance its weight affords to the horizontal pressure of the water which throws the resultant of pressure further from the downstream face; and in the case of the reservoir being empty, although the density of the masonry theoretically makes some difference in the pressure, yet as the reservoir once constructed is seldom emptied, and, when empty, is in no danger of failure, the theoretical difference is not of much importance, and is amply covered by the margin allowed in the factor of safety.

I was therefore led, after due consideration of these points, to neglect altogether the density of the masonry in my approximate formulæ, which, although not *mathematically* correct, give very satisfactory results in very simple form.

Since, however, I have had the advantage of studying M. Bouvier's admirable observations, I have seen my way to recasting my formulæ in a shape which, whilst preserving their simple character, brings them still nearer to his results, and eliminates even the slight discrepancies to which I have alluded above.

In considering the data on which I based my original formulæ, I assumed as correct the density of masonry adopted as an average by M. M. Graeff and Delocre.

M. Bouvier has, however, demonstrated that this density is far too low; and although this does not appreciably affect the formulæ for the down-stream face, it has far greater effect, as I have already observed, on the formulæ for the upstream face.

I have, moreover, thought it desirable to simplify the formulæ still more by dealing with lower numbers, in adopting the unit of tons per square foot, instead of lbs. per square foot, in all calculations.

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My modified formulæ stand as follows :—

$$* \; y = \sqrt{\frac{\cdot 05\, x^3}{A + (\cdot 03 x)}}\;;$$

$$z = \left(\frac{\cdot 09\, x}{A}\right)^4$$

* Notation as before.
A = limit of pressure on the masonry in *tons* per square foot.

In my original formulæ for z I adopted the expression—

$$z = \frac{y}{10}$$

But this, as Major Pennycuick rightly points out, gives more masonry in the upper portion of the up-stream face than is indicated to be necessary by theory. Practically, however, this has some advantages, as it throws back the centre of gravity. Rankine has noticed this, for, when commenting on Major Tulloch's proposal to add masonry to the upper portion of the up-stream face, he remarks—

"The proposal to throw the weight of the wall further inwards than in the French designs tends to realise the principle just stated; and, so far, I fully approve of it."

And the French Engineers appear to have recognised this principle in their more recent works, for, in the Dam de la Terrasse, they have followed out the plan of departure from theory, in this respect, by commencing the batter of the up-stream face at the crown of the dam, carrying out an uniform batter to the base, instead of having the face vertical for a considerable depth, and increasing the batter towards the base in the manner indicated by theory for equalising the pressure thoughout.

In the modified formulæ, however, I have thought it better to adhere as closely as possible to the theoretical profile given by theory, leaving the actual constructors to make such departure from it as they may deem requisite.

Drawing 4 gives ten sections worked out by Bouvier's method, and compared with the results of my modified formulæ; and drawing No. 5 gives a comparison of my formulæ with sections either proposed, or actually executed.

Major Pennycuick in his note has suggested certain modifications* of my original formulæ; but after a careful study I am induced to reject them, as I find that they do not, in the majority of cases, give so close an adherence to theory even as my original formulæ, and in some cases the discrepancy is very considerable.

$$* \; y = 9.\sqrt{\frac{x^3}{P}}$$

and for the up-stream face,
s = Vertical for 40 feet.
Batter = 1 in 20 for 40.
" = 1 in 10 for 40 feet.
" increasing $\frac{1}{10}$ for each additional 40 feet.

Drawing No. 6 gives a sheet of comparative sections illustrating this.

My modified formulæ will be found very useful, not only for ready reference, but also as saving much intermediate labour in fixing a section which will serve as a starting point or basis for the application of Bouvier's formulæ, when it may be desired to undertake more elaborate calculations and investigate the actual stress on different points of the section.

9th June 1883. GUILFORD L. MOLESWORTH.

Mr. Molesworth has in a separate note discussed fully the section which it is proposed to give to the dam across the Periar, and I agree entirely with him that M. Bouvier's section should be adopted in preference to that proposed by Major Pennycuick.

In order to dispose of the water of the river during construction of the dam, Major Pennycuick has provided two culverts, passing under the flanks of the dam; the floorings being only 10 feet above bed of river and 145 feet below maximum water-level in the reservoir above the dam. These culverts are to be closed by self-acting shutters worked by floats and counterpoises, and, when in Madras, the proposed arrangements were explained to me. I then stated that I would never agree to so dangerous an arrangement, and suggested to Colonel Hasted that, if no other means could be contrived for disposing of the water of the river during construction, it might be passed over the dam by means of large syphon tubes. Major Pennycuick in a supplementary note stoutly maintains that his plan is the best of all possible alternatives, that no risk whatever is to be apprehended from its adoption, and that it combines in the highest degree the elements of security, efficiency and economy! However, in case of my objections proving insuperable, he has worked out the probable cost of passing the supply of the river over the dam by means of two large syphon pipes. Having most carefully considered all Major Pennycuick's proposals and arguments, my objections to the culverts remain absolutely insuperable. I cannot conceive how an Engineer of his intelligence could have

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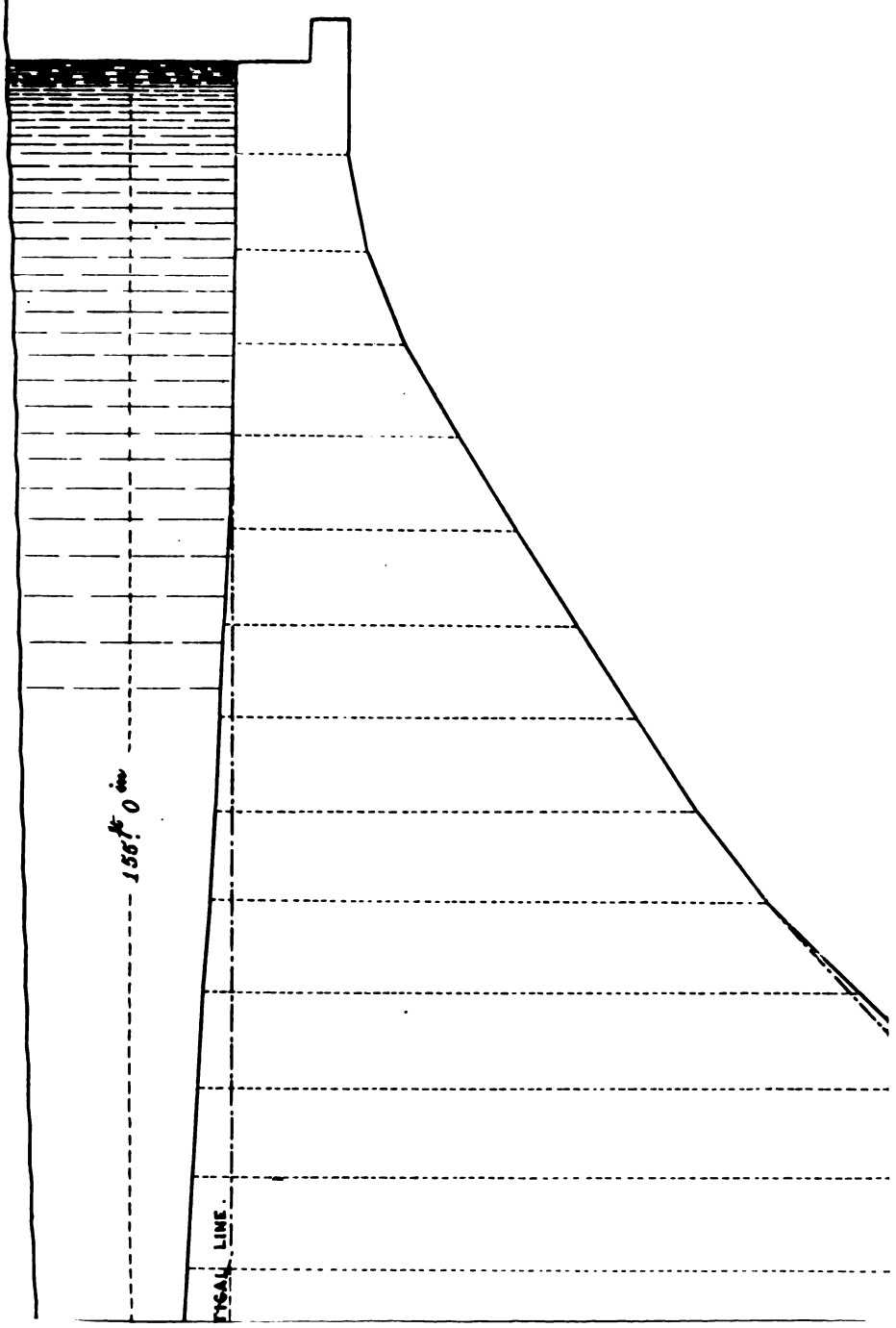
SECTION OF PERIAR DAM.

As proposed by MAJOR PENNYCUICK R.E.

denoted by full lines ———————

Ditto do. do. as determined by M. BOUVIER'S method. }—·—·—·—



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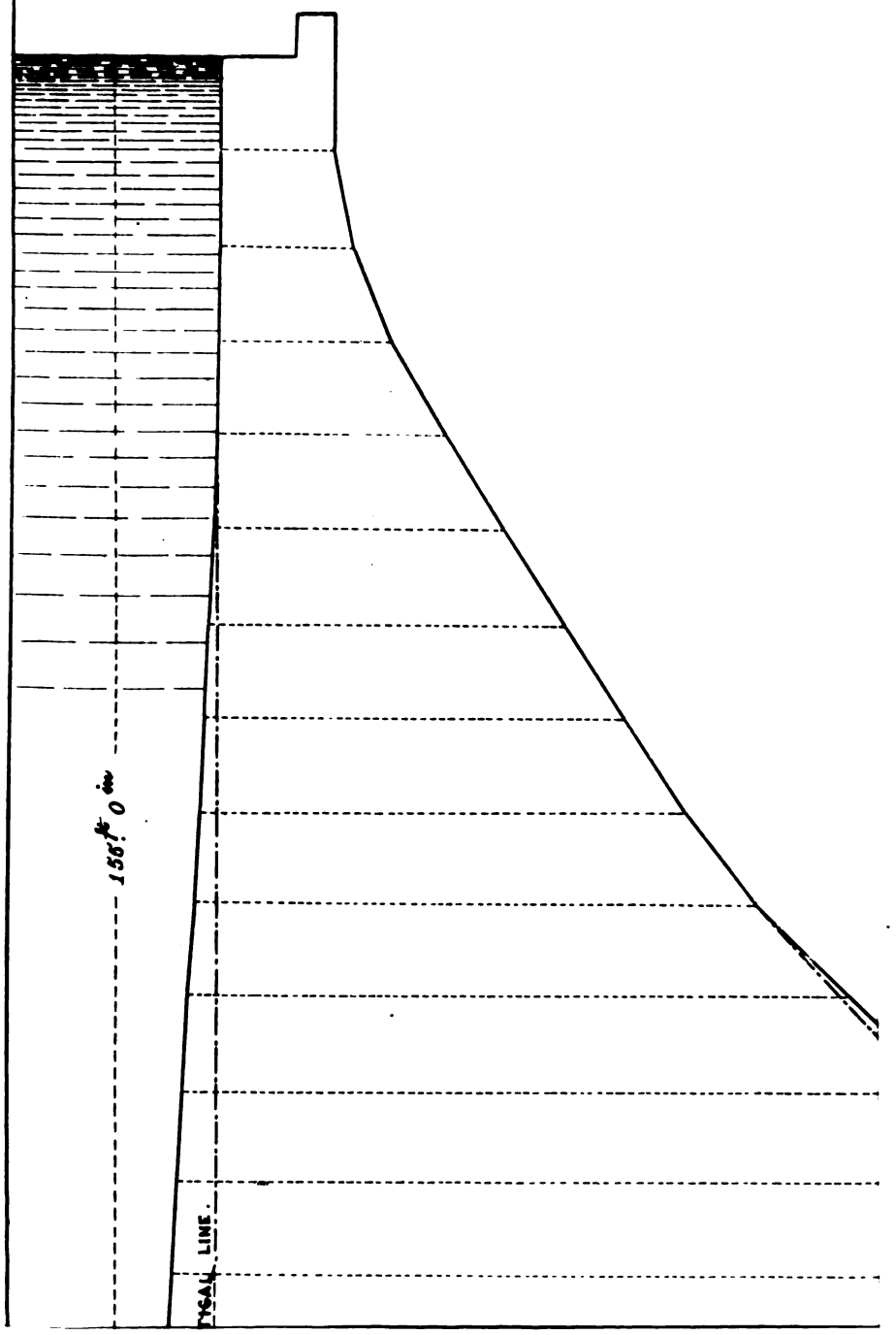
SECTION OF PERIAR DAM.

As proposed by MAJOR PENNYCUICK R.E.

denoted by full lines ———

Ditto do. do. as determined by M. BOUVIER'S method. }—·—·—



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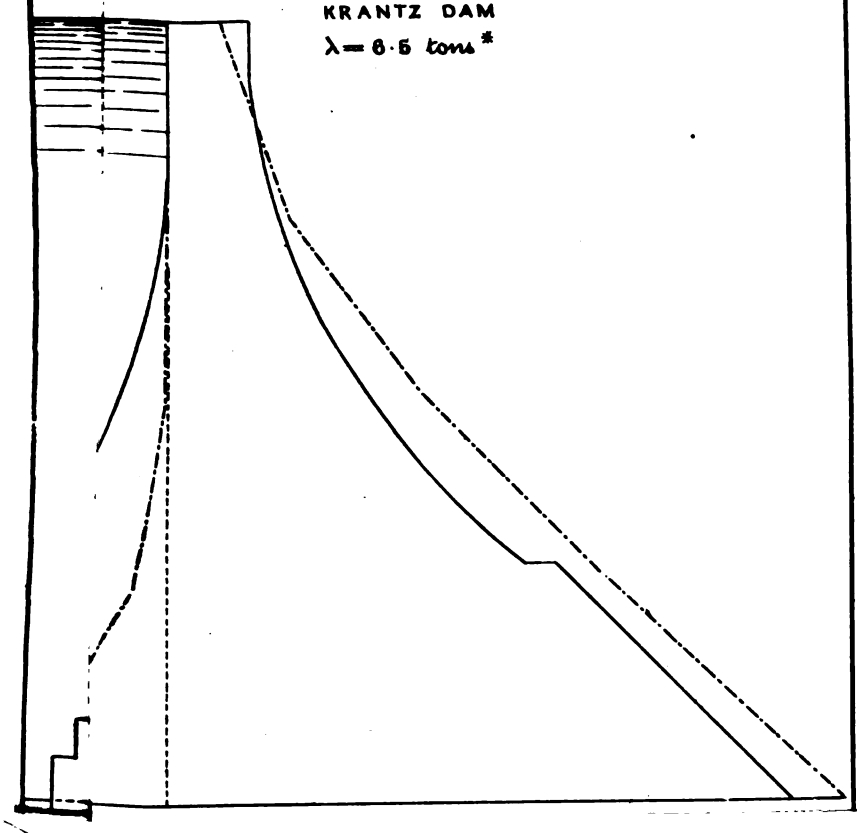
DRAWING Nº 5

ompany note of the Consulting Engineer to the Government
ia, for State Railways, on the PERIAR DAM.
9th June 1883

Guilford L. Molesworth,



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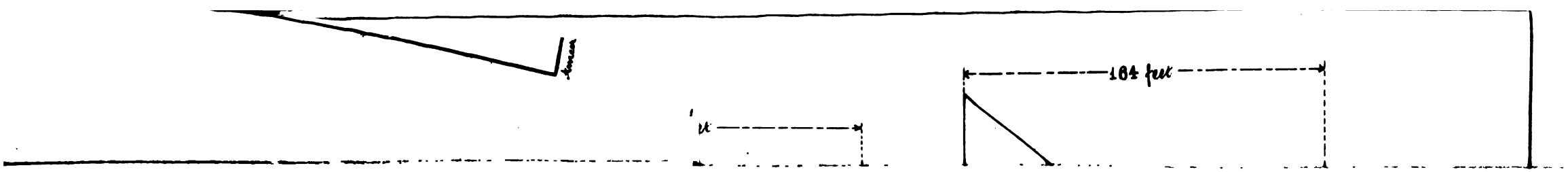

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brought himself to devise such a method of disposing of the escape water. A glance at "Section on C. D.," Sheet No. 10, "Periar Head Works," will shew how soon floating brushwood and grass would clog and jam the self-acting sluice. The "draw" into the tunnel would, of course, be very great, and, unless the floods in the Periar run quite clean and free of floating rubbish, I don't believe the sluice would remain in working order one hour after a flood began to come down. Again, supposing it to remain in perfect order, it is quite plain that the powerful eddy, generated by the cross currents at the entrance of the tunnel, would block the mouth so as to reduce the discharge immensely. This would necessitate a larger section, against the adoption of which Major Pennycuick himself protests. But, again, supposing the tunnels to have answered all expectations during construction, I cannot well imagine a more fatal source of danger to a lofty dam than two culverts passing underneath its flanks, closed by shutters exposed to the enormous pressure due to an average head of at least 135 feet of water!! Major Pennycuick writes of stopping all leakage by strips of vulcanised Indian-rubber, and also of using the openings if necessary to fill the river below! I have no hesitation in saying that, if the water once got way on through the tunnel under such a head, he would find very little of his shutters and gear at the end of ten minutes, and, by the time the lake was empty, he would probably find some irreparable damage done to the dam.

And the whole of this great risk to a magnificent work would have been needlessly incurred. I have carefully considered all the difficulties of passing the water over the dam itself, and see no reason for adopting even the cumbrous, but perfectly safe, expedient of taking it over the dam by syphons. All that we have to dispose of, to keep the main portion of the work dry during five days out of six, is 1,800 cubic feet per second. This volume will flow over 180 feet of the dam with a head of 1 foot 10 inches, and all that is necessary is to keep 180 to 200 feet in length of the masonry on each flank alternately 2 feet and 4 feet below the rest of the work to ensure five uninterrupted days' work out of every six. There is no need to cumber this note with the details of construction of the temporary dam and protective framing and shutters, which I can explain to the Chief Engineer, but the above arrangement can be easily carried out for the estimated cost of the proposed tunnels and self-acting gates *which should on no account be allowed.* It will be enough, in sanctioning the estimate, to say that the proposed culverts under the dam must on no account be constructed, and that there does not seem to be any necessity for making the alternative syphons until it is shown by experience that the water cannot be disposed of, by passing it over depressed portions of the flanks of the dam, with perfect safety and convenience.

Colonel Hasted tells me that one must remain for working the turbines.

If there are no cracks in the rock which forms the watershed ridge, the construction of the tunnel through it may be very considerably expedited by working steadily from both ends.

The works for regulation and distribution of the supply in the channel of the Soorrooly and the Vigay are of ordinary design, and call for no remarks.

The Revenue returns have been specially investigated by Mr. Clogstoun, an Officer of the Settlement Department and checked by the Director of Revenue Settlements. As reduced by the latter Officer, they amount to Rs. 6,58,634, exclusive of any indirect revenue. This amount, and not the 7 lakhs of rupees assumed by the Madras Irrigation Department, should be taken as the gross revenue by Accounts Branch in calculating the returns on capital outlay.

The project is a very bold one, worked out with most commendable care and skill, and I strongly recommend sanction as a Productive Work.

Accounts Branch.

12th July 1883. H. A. B.

No. 28 P.W., dated 27th June 1884.

From—The Government of India,

To—Her Majesty's Secretary of State for India.

In our Despatch No. 74 P. W., dated 22nd May 1876, we stated that a reliable opinion on the soundness of the Periar Project in the Madura district of the Madras Presidency could not be formed without further information on some essential points connected with the scheme. This information has now been received from the Government of Madras, and, subject to the modifications proposed by Mr. G. L. Molesworth, Consulting Engineer to the Government of India for State Railways, and Colonel H. A. Brownlow, R. E., Inspector-General of Irrigation, copies of whose notes are enclosed, the revised project may be accepted as thoroughly sound in all its engineering features. We are therefore in a position to submit, for the approval and sanction of Her Majesty's Government, the complete estimate for the project, amounting to

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R64,39,913, of which R61,85,000 represent the direct, and R2,54,913 the indirect, charges.

2. The object of the scheme is to utilise a portion of the superabundant rainfall on the western slopes of the Ghâts for the purposes of irrigation in the district of Madura to the east of the watershed, where the rainfall is comparatively scanty, and often very uncertain, and where famine has in consequence been severely felt on more than one occasion.

3. The river Periar rises on the western side of the Ghâts and traverses the Native State of Travancore, falling into the sea close to Cochin, and it is proposed to intercept the drainage of 300 square miles of its catchment basin by a dam, constructed opposite to the Goodalur Ghât on the main road between Madras and Travancore. This dam is to be of concrete, 155 feet in height above the deep bed of the river. From the reservoir thus formed the water will be passed by a tunnel constructed through the watershed ridge into the Soorooly, down which it will flow into the Vigay, from which stream it will be distributed over the land by means of weirs and distributary channels.

4. The history and scope of the scheme, and the nature of the proposed works are fully and clearly described in a report by Major J. Pennycuick, R.E., Superintending Engineer, who was specially appointed to revise the designs and estimates for the project, and are reviewed in a brief note, dated 11th April 1883, by Colonel J. O. Hasted, R.E., Acting Chief Engineer for Irrigation, Madras, to which documents we beg to refer Your Lordship for further particulars.

5. It is hoped that the works will be completed in six years, and that in the tenth year after their completion the irrigated area will amount to 101,000 acres. The revenue returns to be expected from the project were most carefully investigated in 1876-77 by Mr. Clogstoun, the Deputy Director of Revenue Settlements, Madras, and the estimate of the growth of irrigation and revenue receipts and charges submitted by the Government of Madras was based on his conclusions. On a reference to the Government of Madras in the Revenue Department we have, however, been informed that Mr. Clogstoun's figures of gross revenue should be modified as below:—

	R
From 85,790 acres of Government land	4,67,374
From 15,210 acres of inam and zemindari land at Rs. 4 an acre	60,840
From second crop irrigation	1,00,000
Total gross revenue	6,28,214

The maintenance charges have been taken at R1,25,400, or about R1·25 per acre irrigated, which may be accepted as fair. The net revenue will therefore amount to R5,02,814, being a return of 7·80 per cent. on the total capital outlay of R64,39,913.

6. The project will thus prove sufficiently remunerative to allow of its being classed as a Productive Public Work, and as it will also secure, in years of scarcity, a large population from the miseries of famine, we strongly recommend it for sanction as a charge against Loan Funds.

7. The forecast Statements Nos. III and IV, submitted by the Government of Madras, have been revised for reasons explained in paragraph 5. The Statement No. II has also been corrected in regard to the provision for leave and pension allowances, and a set of revised statements showing the correct figures, which has been prepared by the Accountant-General in our Public Works Department, is forwarded for Your Lordship's information.

8. The delay in submitting this project to Your Lordship has been chiefly due to the necessity for completing negotiations with the State of Travancore, for the cession of the land required for the head-works and reservoir, and of the water-supply which it is proposed to divert. These negotiations are now almost terminated, the Government of Travancore having agreed to accept the terms of compensation proposed by the Madras Government, including a payment of six lakhs of rupees and the cession of Tangacheri and of certain pattam gardens. A separate communication on this subject will be addressed to Your Lordship by our Government in the Foreign Department.

Documents accompanying.

(1). Endorsement by the Government of Madras, No. 356 I., dated 27th April 1883, and enclosures.

(2). Report by Mr. Clogstoun on the revenue returns of the Periar Project.

(3). Telegram from the Government of Madras in the Revenue Department, dated 6th August 1883.

(4). Note by Mr. Molesworth, dated 9th June 1883, on the Periar Dam.

(5). Note by the Inspector General of Irrigation, dated 12th July 1883.

(6). Revised forecast Statements Nos. II—IV.

(7). Sketch map and 9 plans.

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No. II.

Summary of the estimated indirect charges to capital (excluding interest).

Year.	Capitalization of land revenue abated.	Loss by exchange on payments in England.	Charges for leave and pension allowances.	Total.
1	2	3	4	5
	R	R	R	R
First	...	30,000	7,000	37,000
Second	17,000	2,000	24,500	43,500
Third	17,000	2,000	24,500	43,500
Fourth	17,000	2,000	24,500	43,500
Fifth	17,000	2,000	24,500	43,500
Sixth	17,413	2,000	24,500	43,913
Seventh	...	...	...	...
Eighth	...	...	...	...
TOTAL	85,413	40,000	1,29,500	2,54,913

No. III.

Estimate of growth of irrigation and Revenue receipts and charges.

Year.	Irrigated area at end of year.	REVENUE RECEIPTS AND CHARGES.					
		GROSS REVENUE DUE TO WORKS.				NET REVENUE DUE TO WORKS.	
		Direct receipts.	Enhanced land revenue or indirect receipts.	Total.	Direct and indirect charges on Revenue account.	Including enhanced land revenue.	Excluding enhanced land revenue.
1	2	3	4	5	6	7	8
	Acres.	R	R	R	R	R	R
Seventh	11,000	57,580	4,600	62,180	20,040	42,140	37,540
Eighth	21,000	1,15,874	9,200	1,25,074	40,080	84,994	75,794
Ninth	31,000	1,74,164	13,800	1,87,964	60,120	1,27,844	1,14,044
Tenth	41,000	2,32,454	18,400	2,50,854	80,160	1,70,694	1,52,294
Eleventh	51,000	2,90,745	23,000	3,13,745	1,00,200	2,13,545	1,90,545
Twelfth	61,000	3,49,038	27,600	3,76,638	1,05,440	2,71,398	2,43,798
Thirteenth	71,000	4,07,330	32,200	4,39,530	1,10,280	3,29,250	2,97,050
Fourteenth	81,000	4,65,621	36,800	5,02,421	1,15,320	3,87,101	3,50,301
Fifteenth	91,000	5,23,913	41,400	5,65,313	1,20,360	4,44,953	4,03,553
Sixteeenth	101,000	5,82,214	46,000	6,28,214	1,25,400	5,02,814	4,56,814
Sevententh	101,000	5,82,214	46,000	6,28,214	1,25,400	5,02,814	4,56,814
Eighteenth	101,000	5,82,214	46,000	6,28,214	1,25,400	5,02,814	4,56,814

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No. IV.

Estimate of net Financial Results of 10 years after the probable date of completion of the work.

Year.	Direct capital outlay during the year.	Direct capital outlay to end of year.	Simple interest at 4 per cent. on capital outlay to end of previous year, *plus* half outlay during year.	Net revenue, including enhanced land revenue, column 7 of Table III.	Simple interest, less net revenue.	Net revenue, less simple interest.
1	2	3	4	5	6	7
	₹	₹	₹	₹	₹	₹
First	4,55,000	4,55,000	9,100	...	9,100	...
Second . . .	9,86,000	14,41,000	37,920	...	37,920	...
Third	9,86,000	24,27,000	77,360	...	77,360	...
Fourth . . .	9,86,000	34,13,000	1,16,800	...	1,16,800	...
Fifth	9,86,000	43,99,000	1,56,240	...	1,56,240	...
Sixth	9,86,000	53,85,000	1,95,680	...	1,95,680	...
Seventh . . .	4,00,000	57,85,000	2,23,400	42,140	1,81,260	...
Eighth . .	4,00,000	61,85,000	2,39,400	84,994	1,54,406	...
Ninth . .	...	61,85,000	2,47,400	1,27,844	1,19,556	...
Tenth . . .	...	61,85,000	2,47,400	1,70,694	76,706	...
Eleventh . . .	...	61,85,000	2,47,400	2,13,545	33,855	...
Twelfth . . .	...	61,85,000	2,47,400	2,71,398	...	23,998
Thirteenth . . .	...	61,85,000	2,47,400	3,29,250	...	81,850
Fourteenth . . .	...	61,85,000	2,47,400	3,87,101	...	1,39,701
Fifteenth . . .	...	61,85,000	2,47,000	4,44,953	...	1,97,553
Sixteenth . . .	...	61,85,000	2,47,400	5,02,814	...	2,55,414
Seventeenth . .	...	61,85,000	2,47,400	5,02,814	...	2,55,414
Eighteenth . . .	...	61,85,000	2,47,400	5,02,814	...	2,55,414
TOTAL . .	...	...	35,29,900	35,80,361	...	50,461

No. 53, dated 18th September 1884.

From—Her Majesty's Secretary of State for India,

To—The Government of India.

Your Excellency's Public Works and Political letters, numbered respectively 28 and 31, and dated the 27th June 1884, regarding the Periar irrigation project in the Madras Presidency, have received my consideration in Council.

2. This project has been for some time under discussion by the Irrigation authorities in Madras, proposals with the same object having been made so far back as 1867 by Major Ryves, and later by Major (then Lieutenant) Pennycuick, R.E., and Mr. R. Smith. The present scheme has, after considerable labour and personal investigation, been elaborated by Major J. Pennycuick, R.E., and, subject to certain modifications suggested by your Consulting Engineer for State Railways and your Inspector-General of Irrigation, you have come to the conclusion that it is one which is thoroughly sound in its engineering features, and that it may be undertaken as a Productive Public Work at a total estimated cost of ₹64,39,913.

3. The object of the work is, as described in your letter, to utilize a portion of the superabundant rainfall on the western slopes of the Ghâts for the purposes of irrigation in the district of Madura to the east of the watershed where the rainfall is comparatively scanty and often very uncertain, and where famine has in consequence been severely felt on more than one occasion, and it is proposed to accomplish this object by diverting to the eastern side of the Ghâts the waters of the river Periar, which flows on the western side.

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4. The engineering features of the scheme are of an unusual character. The headworks or the catchment of the water are to consist of a dam, 155 feet in height, made of concrete, and the channels to the point of distribution, which will be at a distance of between 80 and 90 miles from the headworks, include a subterranean aqueduct 6,650 feet in length. The project has not, however, reached its present stage without having been studied long and carefully by the officers specially employed in preparing it, and with certain modifications it has received the final approval of your professional advisers, whose comments and conclusions should certainly be acted on in the actual prosecution of the design. There seems to be no doubt of its success if carried out with skill and judgment.

5. With regard to the financial aspect of the work, the estimates of revenue to be derived from its operations, based on Mr. Clogstoun's report of 1876, are of a favourable character, the gross revenue being estimated at R6,28,214, while, after deducting maintenance charges (calculated at R1·25 per acre irrigated) amounting to R1,25,400, a net revenue of R5,02,814 per annum, or 7·80 per cent., is looked for on the capital outlay of R64,39,913.

6. Such an estimated return fulfils the conditions required to admit of its being made from borrowed funds; but experience shows that estimates, however carefully made, are in the case of all large engineering projects, and more specially those in which running water has to be controlled, frequently departed from, and a work of this importance and character will require the exercise of the greatest vigilance and care to keep it within the limits specified.

7. But irrespective of the direct pecuniary returns to be looked for from the scheme, the additional protection that will be given to the district of Madura from the effects of scarcity and famine must be taken into account in appreciating its value. It will be recollected that the Famine Commission drew special attention* to the danger the population of this district was exposed to, and mentioned the Periar scheme as one that should not be lost sight of.

* Report, Part II, paragraph 47.

8. Under all these circumstances, and on the assurance which Your Excellency's Government has conveyed to me that you are satisfied as to the engineering soundness and the financial prospects of the project, I have decided, subject to a satisfactory arrangement being made with the Travancore State for the cession of the requisite land, to which further reference will be made hereafter, to sanction it at a total estimated cost of R64,39,913, of which R61,85,000 represent direct, and R2,54,913 indirect, charges.

9. There remains one further and important matter to be noticed in connection with this scheme. Your Excellency has, by your Political letter No. 81, dated 27th June 1884, suggested that, in return for the cession of land required for the headworks by the Travancore State, Her Majesty's Government should, besides making a money-payment of six lacs of rupees, cede to the Travancore State the small Christian Settlement of Tangacheri, together with certain Patam gardens, all in the neighbourhood of Quilon. The inhabitants of Tangacheri object strongly to the proposed transfer, and although your Government have made enquiries and have apparently satisfied yourselves that they would suffer no substantial hardship thereby, I am unable, in the face of their distinct opposition, to assent to the measure proposed, and I must ask your Government to reconsider the subject, with a view of devising some other means, whether in the shape of an increased pecuniary grant or an annual payment, or otherwise, by which the just claims of the Travancore State for compensation for the land to be ceded by them may be duly met by Her Majesty's Government.

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